Individual QI projects from single institutions

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Reducing Blood Testing in Pediatric Patients after Heart Surgery: Proving Sustainability

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Abstract

Introduction: Frequent blood testing increases risk of iatrogenic anemia, infection, and blood transfusion. This study describes 3 years of sustained blood testing reduction from a quality improvement (QI) initiative which began in 2011. **Methods:** The cohort consisted of postop children whose surgery had a Risk Adjustment for Congenital Heart Surgery (RACHS) classification consecutively admitted to a tertiary Cardiac Intensive Care Unit. Data were collected for a 2010 preintervention, 2011 intervention, and 2012–13 postintervention periods, tabulating common laboratory studies per patient (labs/pt) and adjusted for length of stay (labs/pt/d). The QI initiative eliminated standing laboratory orders and changed to testing based on individualized patient condition. Adverse outcomes data were collected including reintubation, central line–associated bloodstream infections and hospital mortality. Safety was measured by the number of abnormal laboratory studies, electrolyte replacements, code blue events, and arrhythmias. **Results:** A total of 1169 patients were enrolled (303 preintervention, 315 intervention, and 551 postintervention periods). The number of labs/pt after the QI intervention was sustained (38 vs. 23 vs. 23) and labs/pt/d (15 vs. 11 vs. 10). The postintervention group had greater surgical complexity ($P = 0.002$), were significantly younger ($P = 0.002$) and smaller ($P = 0.008$). Children with RACHS 3–4 classification in the postintervention phase had significant increased risk of reintubation and arrhythmias. **Conclusions:** After the implementation of a QI initiative, blood testing was reduced and sustained in young, complex children after heart surgery. This may or may not have contributed to greater reintubation and arrhythmias among patients with RACHS 3–4 category procedures. *(Pediatr Qual Saf 2017;2:e047; doi: 10.1097/pq9.0000000000000047; Published online December 7, 2017.)*

INTRODUCTION

Pediatric patients admitted to Cardiac Intensive Care Units (CICUs) after heart surgery require vigilant monitoring. Frequent blood testing is essential in the assessment and management of critically ill patients, but carries risk of anemia, infection, and transfusions.[1–5] A quality improvement (QI) initiative implemented in 2011 reduced blood testing per patient in our CICU by 41% (39 vs. 67 labs/pt) when compared with 2010. However, the sustainability of the change had not been studied.

The strategies implemented during the initial QI consisted of a revised preprinted postoperative order set, including laboratory choices at the time of CICU admission, the following morning, and unlimited as needed electrolyte tests nurses could freely draw as they thought were needed. Education and ongoing feedback to providers established an increased confidence in high clinical vigilance, including noninvasive monitoring and clinical triggers. Heart Center team engagement and feedback was valued.[6] Many health-care improvement initiatives face the challenge of sustaining change until habits and routine become embedded within organizations.[7–10] Our aim was to evaluate whether prior reductions in laboratory testing were sustained in postoperative children during the 2 subsequent years after the original interventions. We describe the impact of the QI initiative

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What is known on this subject: *To date, there is one known study published reporting the safety and feasibility of reducing blood testing for pediatric patients in a critical care unit. Sustainability in such quality improvement projects has not been reported.*

What this study adds: *Blood testing is necessary in ICUs for management and monitoring of critically ill patients. As other studies have demonstrated, blood testing reduction can be safe and an effective way of blood conservation, preventing iatrogenic anemia and blood transfusion risks.*

on different laboratory tests and among different surgeries grouped using Risk Adjustment for Congenital Heart Surgery (RACHS) categories. To ensure study safety, several balance measures were analyzed including rates of reintubation, abnormal laboratory values, and proportion of patients requiring electrolyte replacements, arrhythmias, and code blue events.

METHODS

Setting and Context

This is a retrospective, single-center study conducted in the 16-bed CICU at Primary Children's Hospital (PCH) in Salt Lake City, Utah. PCH is a 289-bed, free-standing children's hospital, serving 6 states in the western region of the United States with approximately 400 open-heart surgeries annually.

Interventions

In 2011, a multidisciplinary QI team consisting of Heart Center physicians, surgeons, nurse practitioners, registered nurses, patient care assistants, and unit clerks was established. Laboratory test ordering and collection practice was examined for postsurgical patients during their CICU length of stay (LOS).

The QI team developed a key driver diagram (Fig. 1), identifying interventions and strategies to reduce and sustain laboratory testing. During initial project implementation in 2010–11, the team created and utilized a new postoperative order set that included a list of laboratory tests that could be selected at CICU admission and the following morning. After postoperative day 1, morning round discussion included ordering laboratory tests appropriately per individual patient and eliminating multiple entries into invasive catheters by consolidating blood sampling to specific times. However, the numbers of laboratory tests were not limited and providers could change them when clinically appropriate. Verbal and "as needed" orders were eliminated. Noninvasive monitoring was utilized more extensively such as end-tidal carbon dioxide and near-infrared spectroscopy. Recommendations for laboratory ordering was identified based on certain clinical triggers such as low cardiac output, vasoactive medications, arrhythmias, bleeding, fevers, urine output, and parenteral nutrition. Critical thinking and frequent assessment was encouraged for all providers. A checklist prompting discussion regarding appropriate laboratory testing for individual patients was utilized in morning rounds.

Cohort Identification

Postoperative heart patients who had procedures classified by RACHS categories from January 1, 2010 to December 31, 2013 were included. The preintervention period included patients admitted from January 1 to December 31, 2010, the intervention from January 1 to December 31, 2011, and the postintervention from January 1, 2012 to December 31, 2013. The Cardioaccess Database was utilized to obtain assigned RACHS classification, as well as reintubation, arrhythmias, and code blue events. Patients were excluded if the procedure did not have RACHS classification, required extracorporeal membrane oxygenation, or if the CICU LOS was greater than 30 days.

Measures

Outcome measures include the overall number of laboratory tests per patient (labs/pt) and the number of laboratory test per patient adjusted for CICU LOS (labs/

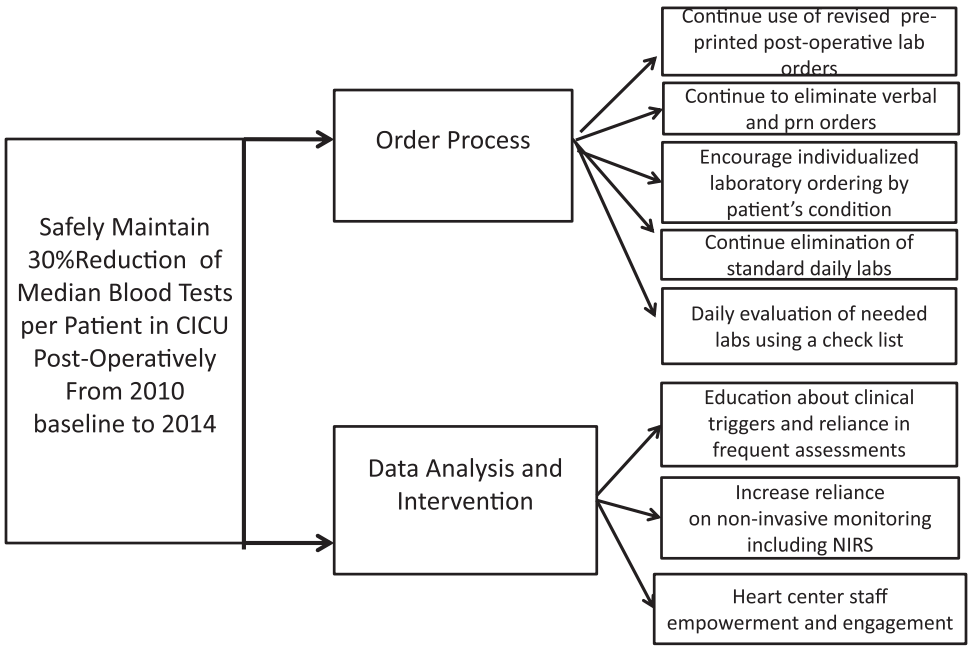

Fig. 1. Maintenance of median number of blood tests per patient by complexity of surgery after cardiac surgery at reduction level.

pt/d). The laboratory tests tabulated included any blood gas (BG), basic metabolic (BMP), renal function (RFP), comprehensive metabolic panels (CMP), isolated potassium (K), ionized calcium (iCa), phosphorus (PO4), albumin, magnesium (Mg), as well as prothrombin time (PT), partial thromboplastin time (PTT), fibrinogen, complete blood counts with and without differential (CBCs), single hemoglobin (Hg), and hematocrit (HCT), blood cultures, and any lactic acid (LA) sample. Tests were grouped into categories to capture those that are interchangeable and determine if any decreased. Laboratory tests were grouped as follows: any blood gas (arterial, venous, capillary, and point of care), metabolic panels (BMP, CMP, and RFP), individual electrolytes (K, iCa, Mg, PO4), coagulation profile (prothrombin time, partial thromboplastin time, and fibrinogen), LA (arterial, venous, capillary, and point of care), any hemoglobin (CBCs, single Hg with and without HCT). Further analysis for the grouped laboratory categories was analyzed as labs/pt and labs/pt/d. RACHS categories combined into 3 groups: 1–2, 3–4, and 5–6. Other outcome measures included central line–associated blood stream infections (CLABSIs) and hospital mortality.

Balance measure events reported were rates of reintubation (defined as need of unplanned reintubation within 48 hours of extubation),[11] and the proportion of patients with documented arrhythmias and code blue events in the CICU by RACHS groups. New arrhythmias were classified according to therapy: no intervention, medicated, pacing alone, pacing and medication combined, or a permanent pacemaker. Abnormal laboratory studies such as LA > 2 mmol/L units, pH < 7.35, Mg < 2 mg/dL, K < 3.5 mmol/L, and iCa < 1.2 mmol/L were calculated per patient within RACHS groups, the percentage of patients receiving electrolyte replacements, and the number of electrolyte replacements per patient per group during each study period were also calculated.

Methods of Evaluation

Data were retrospectively collected through chart review and Cardioaccess Database. General demographic data collected include age, weight, RACHS classification, CICU LOS, and length of intubation. The most common laboratory tests as cataloged above were counted per patient and adjusted for LOS. Preintervention, intervention, and postintervention groups were compared using statistical process control u-charts assessing the number of laboratories per patient (Fig. 2). Patients were consolidated into quarters for evaluation. An 8-point rule was applied to evaluate the process. Further analysis of the common laboratory tests, total labs/pt and labs/pt/d, was conducted for the combined RACHS groups.

Statistical Analysis

Continuous patient characteristics and outcomes were summarized by the median and interquartile range (IQR) and categorical variables by count and percentage. Primary outcomes and balance measures were compared between the 3 study periods. Only the first surgery was included among patients who had more than one surgery during the study period, as repeat measures within subjects violate the independence assumption of conventional statistical tests. Continuous variables were analyzed using a Wilcoxon rank sum test due to skewed distributions, and categorical variables using a Fisher's exact or chi-square test. Statistical significance was defined as $P < 0.05$ and the balance measures significance at $P < 0.0167$ after adjusting for the Bonferroni. *P* value 1 is the result of comparing 2010 vs. 2011 and *P* 2 comparing 2011 vs. 2012–13. All data were analyzed using SPSS 22 for Windows (SPSS, Chicago, Ill.) or R v. 3.0.3 (Vienna, Australia).

Ethical Considerations

The study was approved by the University of Utah Institutional Review Board and granted a waiver of requirement for informed consent. No conflicts of interest were identified.

RESULTS

A total of 1169 postsurgical patients were studied consisting of 303 patients in 2010, 315 in the 2011, and 551 in 2012–13. There were 1034 patients with 1 procedure, 123 with 2, and 12 with 3. Table 1 presents demographic and clinical characteristics of patients treated during the 3 study periods. More than 50% of the patients across all study years were younger than 1 year of age, were <10 kg, had CICU LOS < 3 days, and were intubated for 24 hours or less. The postintervention group was younger (161 days vs. 249 days; $P = 0.002$), weighed less (6 kg vs. 7 kg; $P = 0.008$) and had a significantly higher complexity RACHS classification ($P = 0.002$) than the 2011 intervention group. Additionally, patients with RACHS class 3–4 procedures increased 10%. No difference in the CICU LOS (2 days vs. 2 days; $P = 0.84$) or intubation hours (10 hours vs. 11 hours; $P = 0.91$) occurred between the postintervention and intervention groups.

An increase in excluded patients in the postintervention group compared with the intervention group was statistically significant (n = 125 vs. 47; $P = 0.02$), consisting of procedures without RACHS classification [94 (75%) vs. 39 (83%)], CICU LOS > 30 days [12 (10%) vs. 3 (6%)]; or received extracorporeal membrane oxygenation [15(12%) vs. 3(6%)].

Table 2 describes the primary outcomes across all study years. The median labs/pt significantly decreased by 40% (23 vs. 38; $P < 0.001$) comparing the intervention to preintervention group and subsequently sustained during postintervention (23 vs. 23; $P = 0.78$). A similar laboratory reduction and sustained pattern was noted when adjusted for CICU LOS, (11 vs. 15; $P < 0.001$); (10 vs. 11, $P = 0.45$). Labs/pt among study groups were similar, suggesting that monitoring and vigilance were

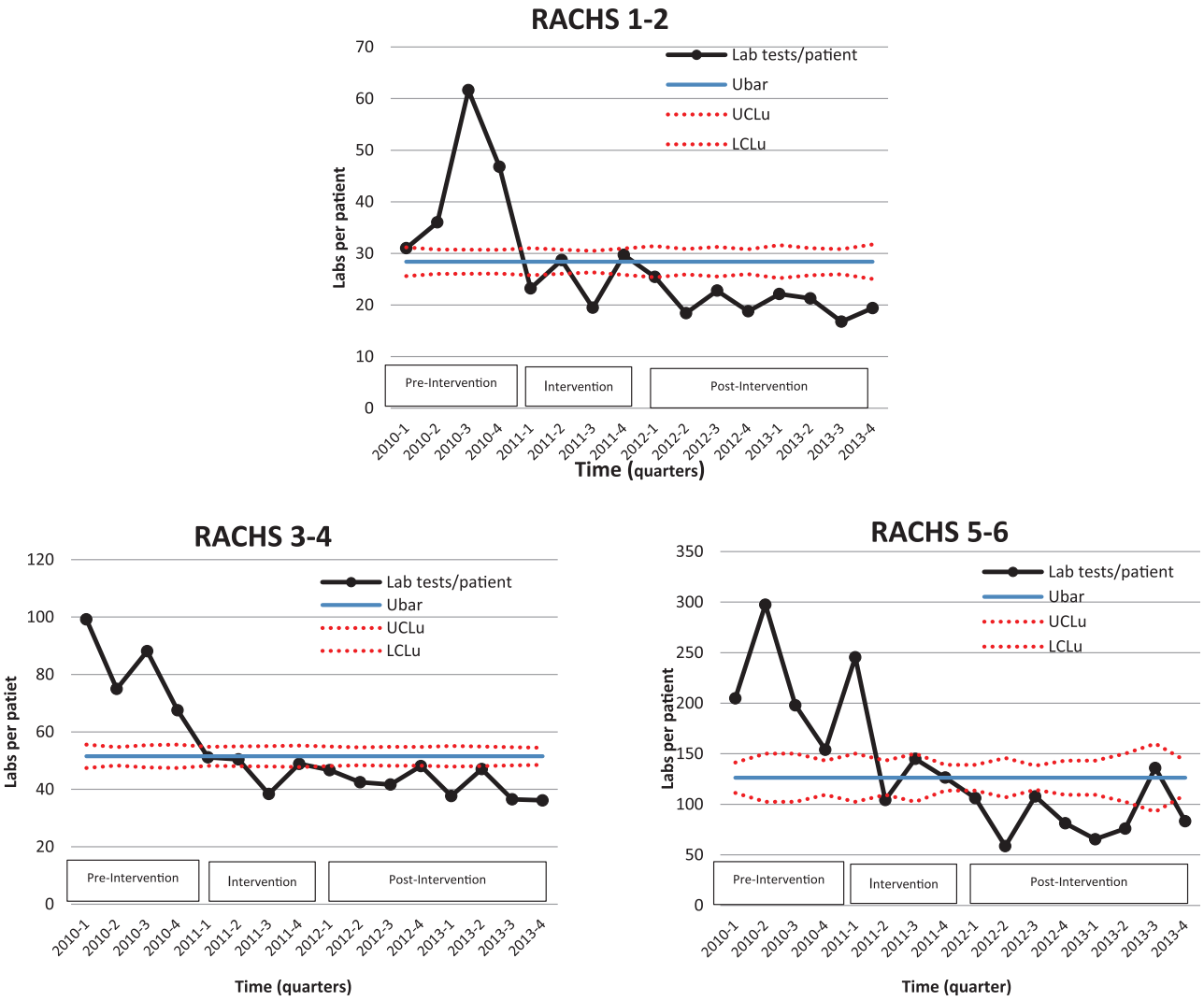

Fig. 2. Control u-charts with quarterly number of laboratory tests per patient from 2010 to 2013 starting with the preintervention period. Time is consolidated into quarters. Ubar, average number of laboratories per patient; UCLu, upper control limit for u-chart; LCLu, lower control limit for u-chart.

the same. However, when adjusted by LOS, labs/pt/d was significantly decreased in the intervention period but not further in the postintervention period. RACHS groups (1–2, 3–4, 5–6) were impacted differently, noting a continual decrease comparing postintervention period with the intervention period. Postintervention patients with RACHS 1–2 procedures had a significant reduction in the labs/pt (16 vs. 18; $P = 0.04$), specifically any BG (2 vs. 3; $P = 0.01$) and any Hg [2 (IQR 1–4) vs. 2 (IQR 1–5); $P = 0.03$]. In the RACHS 3–4 group, labs/pt/d also were significantly decreased (10 vs. 11; $P = 0.03$). The largest laboratory testing reduction was noted among patients in RACHS 5–6 with significantly fewer total labs/pt (88 vs. 113; $P = 0.04$), labs/pt/d (9 vs. 11; $P = 0.04$), and specifically any BG (24 vs. 30; $P = 0.02$, and any Hg (7 vs. 10; $P = 0.03$). Central line days, CLABSI, and mortality to discharge rates were similar across all years.

Table 3 shows the analyzed balance measures by intervention periods. The postintervention group, specifically RACHS category 3–4 procedures, had significantly higher proportion of arrhythmias and reintubation rates (16% vs. 4%; $P < 0.001$) (13% vs. 2%; $P < 0.001$), without an increase in code blue across RACHS groups and intervention periods. Abnormal labs/pt were evaluated by RACHS groups. A significant decrease in abnormal magnesium levels occurred between intervention and preintervention periods for all RACHS groups, respectively: [1(IQR 0–2) vs. 1(IQR 0–3), $P = 0.004$; 1(IQR 0–3) vs. 3(IQR 2–6), $P < 0.001$; and 5(IQR 2–9) vs. 9(7–16); $P = 0.03$]. However, the postintervention RACHS 3–4 procedures demonstrated an increase in abnormally low magnesium levels in comparison to the intervention period (2[1–3] vs. 1[0–3]; $P = 0.012$).

Further analysis of reintubation among patients with RACHS 3–4 procedures was explored given their higher rates of reintubation and arrhythmias. The postintervention group had significantly smaller median weight (5 kg vs. 8 kg; $P = 0.03$) and were younger (152 days vs. 351

Table 1. Clinical Characteristics and General Demographics Comparing Time Periods

Variable	Preintervention 2010 (N = 303)	Intervention 2011 (N = 315)	Postintervention 2012–2013 (N = 551)	*P**	*P*†
RACHS (n, %)					
Class 1–2	159 (52%)	166 (53%)	223 (40%)	0.85	<0.001
Class 3–4	132 (44%)	134 (43%)	296 (54%)	0.95	0.002
Class 5–6	12 (4%)	15 (5%)	32 (6%)	0.78	0.54
Age (d), median (IQR)	208 (29–1344)	249 (40–1512)	161 (12–1382)	0.40	0.002
Age groups (n, %)					
<30 d	78 (26%)	76 (24%)	183 (33%)	0.64	0.007
31–60 d	3 (1%)	9 (3%)	17 (3%)	0.15	0.67
61 days to 1 year	98 (32%)	85 (27%)	157 (28%)	0.17	0.69
>1 year	124 (41%)	145 (46%)	194 (35%)	0.20	0.002
Weight (kg), median (IQR) Weight groups (n, %)	7 (4–15)	7 (4–15)	6(3–14)	0.50	0.008
<4 kg	75 (25%)	87 (28%)	186 (34%)	0.66	0.07
4–10 kg	121 (40%)	104 (33%)	184 (33%)	0.15	0.98
>10 kg	107 (35%)	124 (39%)	181 (33%)	0.29	0.07
CICU LOS (d), median (IQR) Time periods (n, %)	3 (1–5)	2 (1–4)	2 (1–5)	0.05	0.84
<24 h	29 (10%)	22 (7%)	47 (9%)	0.24	0.40
1–3 days	142 (47%)	176 (56%)	291 (53%)	0.03	0.53
3–5 days	57 (19%)	48 (15%)	69 (13%)	0.33	0.21
>5 days	75 (25%)	68 (22%)	138 (25%)	0.30	0.23
Intubation time (h), median (IQR) Time periods (n, %)	10 (0–33)	11 (0–37)	10 (0–47)	0.57	0.91
<6 h	131 (43%)	143 (45%)	246 (45%)	0.54	0.92
6–24 h	93 (31%)	81 (26%)	121 (22%)	0.23	0.23
>24 h	79 (26%)	91 (29%)	184 (33%)	0.60	0.23
Excluded					
Total excluded patients per period (n, %)	56 (15%)	47 (12%)	125 (18%)	0.33	0.02
No RACHS classification (n, %)	49 (87%)	39 (83%)	94 (75%)	0.51	0.28
CICU LOS >30 d	6 (10%)	3 (6%)	12 (10%)	0.50	0.76
ECMO (n, %)	2 (3.5%)	3 (6%)	15 (12%)	0.65	0.40
ECMO + CICU LOS >30 d (n, %)	1 (1.7%)	2 (5%)	4 (3%)	0.60	0.66
Age (d), median (IQR)	1077 (123–4041)	1647 (129–4807)	319 (76–2879)	0.84	0.11
CICU LOS (d), median (IQR)	3 (2–9)	3 (1–6)	4 (1–13)	0.25	0.08

**P* value comparing preintervention vs. intervention.
†*P* value comparing intervention vs. postintervention.
ECMO, extracorporeal membrane oxygenation.

Table 2. Primary Outcomes and Time

Variable No. Tests/Patient	Preintervention 2010 (n = 303) Median (IQR)	Intervention 2011 (n = 315) Median (IQR)	Postintervention 2012–13 (n = 551) Median (IQR)	*P**	*P*†
Labs/patient‡,§,‖	38 (24–67)	23 (16–46)	23 (16–44)	<0.001	0.78
Labs/patient/d‖,¶,**	15 (11–18)	11 (8–13)	10 (8–13)	<0.001	0.45
Blood gases‡,§,‖	7 (4–16)	4 (2–10)	3 (2–9)	<0.001	0.55
Metabolic panels	3 (2–6)	3 (2–6)	3 (2–7)	0.86	0.62
Single electrolyte§,**,††	16 (10–32)	8 (5–17)	8 (5–15)	<0.001	0.58
Hemoglobin‡,§,‖,‡‡	4 (3–6)	3 (2–4)	2 (2–4)	<0.001	0.81
Coagulation profile§,**	3 (3–6)	3 (3–3)	3 (3–3)	0.003	0.36
Lactic acid§	2 (1–4)	2 (1–4)	2 (1–5)	0.17	0.05
CLABSI (n, %)	2 (1%)	3 (1%)	5 (1%)	>0.99	>0.99
Mortality to discharge (n, %)	2 (1%)	2 (1%)	2 (0%)	>0.99	0.62
Excluded	**2010 (n = 56)**	**2011 (n = 47)**	**2012–13 (n = 125)**		
Labs/patient	40 (16–97)	25 (7–51)	29 (10–125)	0.07	0.26
Labs/patient/d	13 (8–16)	9 (5–11)	7 (5–12)	0.001	0.78

ABG, arterial blood gas; CBG, capillary blood gas; CBC with diff, complete blood count with differential; CBC w/o diff, complete blood cell count without differential; Fib, fibrinogen; Hb, hemoglobin, HCT, hematocrit; iCa, ionized calcium; K, potassium; LA, lactic acid; Mg, magnesium; n, number of patients; PO4, phosphorus; POC, point of care; PT, pro-thrombin time; PTT, partial thromboplastin time; VBG, venous blood gas.
Blood gases include ABG, VBG, POC, and CBG. Single electrolyte includes K, iCa, PO4, and Mg. Metabolic panels include all basic metabolic profile, renal function panel, and comprehensive metabolic. Coagulation profile includes all PT, PTT, and Fib. Hemoglobin includes all CBC with diff, CBC w/o diff, Hb, and HCT.
**P* value comparing preintervention vs. intervention.
†*P* value comparing intervention vs. postintervention.
‡Statistically significant in RACHS class 1–2 comparing all periods.
§Comparing preintervention vs. intervention.
‖Statistically significant in RACHS class 5–6 comparing all periods.
¶Statistically significant in RACHS class 3–4 comparing all periods.
**Comparing preintervention vs. intervention.
††Comparing preintervention vs. intervention.
‡‡Comparing intervention vs. postintervention.

Table 3. Balance Measure Outcomes and Abnormal Laboratory Studies and Blood Gases Per Patient

Balance Measure	Preintervention 2010 (N = 303)	Intervention 2011 (N = 315)	Postintervention 2012–13 (N = 551)	*P**	*P*†
Reintubation (n, %)‡	15 (5%)	17 (5%)	56 (10%)	0.80	0.02
Code blue (n, %)	8 (3%)	5 (2%)	6 (1%)	0.41	0.54
Arrhythmia (n, %)‡	15 (5%)	8 (3%)	63 (11%)	0.17	<0.001
Treatment					
No intervention	1	1	11		
Medication	5	0	18		
Temporary pacing	2	2	22		
Pacing and medication	2	1	7		
Permanent pacer	5	4	5		
Blood gases before first extubation/patient, median (IQR)§,‖,¶	6 (4–13)	5 (3–10)	6 (4–11)	0.002	0.05
Number of abnormal laboratory tests/patient, median (IQR)					
Lactic acid >2 mmol/L	1 (0–2)	1 (0–2)	1 (0–3)	0.32	0.15
pH < 7.35	2 (1–5)	2 (1–4)	2 (1–4)	0.75	0.97
Magnesium <2 mg/dL §,‖,¶	2 (1–5)	1 (0–3)	2 (1–3)	<0.001	<0.001
Potassium <3.5 mmol/L	1 (0–4)	1 (0–4)	1 (0–4)	0.11	0.07
Ionized calcium <1.2 mmol/L	0 (0–1)	0 (0–1)	0 (0–1)	0.21	0.08
Patients treated with IV supplement (n, %)					
Calcium	259 (85%)	280 (88%)	481 (87%)	0.23	0.56
Magnesium	270 (89%)	284 (90%)	517 (93%)	0.69	0.06
Potassium	254 (83%)	265 (84%)	451 (82%)	1.00	0.45
Electrolyte replacements/patient, median (IQR)					
Calcium	1 (1–2)	2 (1–2)	2 (1–3)	0.28	0.71
Magnesium§,‖,¶	2 (1–5)	1 (1–3)	2 (1–3)	<0.001	0.09
Potassium§	2 (1–5)	2 (1–4)	2 (1–5)	0.06	0.46

n, number of patients.
**P* value comparing preintervention vs. intervention period.
†*P* value comparing intervention vs. post-intervention period.
‡Comparing intervention vs. postintervention period.
§Comparing preintervention vs. intervention period.
‖Comparing preintervention vs. intervention period.
¶Comparing preintervention vs. intervention period.

days; $P = 0.03$) than the intervention group. Causes for the 39 reintubations during the postintervention period included 17 (56%) for respiratory failure, 5 (17%) cardiac arrest or low cardiac output syndrome (including sepsis), 6 (20%) for procedures, and 2 (6%) for airway management (ie, seizures). The total number of any blood gases per patient before initial extubation did not decrease during the postintervention period nor did the number of blood tests with abnormally low pH. In fact, when analyzing all groups by year, there was an increase of median blood gases before the first extubation from postintervention to intervention (6 vs. 4; $P = 0.05$) (Table 3). More than 80% of arrhythmias encountered across all study years combined were treated, including medication administration, pacing, medication and pacing combined, or a permanent pacemaker. Increased permanent pacemaker placement occurred during the intervention period, compromising 50% of patients with arrhythmias.

Statistical process control u-charts for all RACHS groups evaluated in quarters reveal a sustained shift in decreasing the labs/pt from the preintervention period (Fig. 2). RACHS 3–4 chart demonstrates a greater degree of variation in relation to the other 2 groups, suggesting a process that was not stable or "in control." This may indicate increased laboratory needs driven by a sicker population than during previous years. The most dramatic change is RACHS 5–6 with ongoing decline in mean labs/pt into the postintervention period.

DISCUSSION

After the implementation of a QI initiative, a sustained reduction in blood testing was maintained for labs/pt and labs/pt/d in young, complex children after heart surgery.[6] This transpired in the setting of higher surgical complexity, despite smaller and younger patients. Although the reduction in laboratory tests was sustained, we found a significant increase in some balance measure events among the postintervention RACHS 3–4 subgroup, suggesting a potential for harm.

The sustainability results of this initiative are similar to several reports addressing issues of blood testing in adults. Kumwilaisak et al implemented laboratory guidelines in an adult surgical intensive care unit. A 37% decrease in the number of laboratory test per patient was achieved and sustained for 1 year implementation without a difference in survival rates, days on mechanical ventilation, ICU LOS, or ICU readmission rates.[12] Similarly, Ratnaike et al[13] reported maintenance of a 42% reduction in the average number of tests per admission for 6 months after implementation of recommended practice guidelines for chest pain in adults. The authors found no effect on bed days per admission or emergency readmission rates.

We attribute our QI project sustainability of judicious blood testing to preprinted order set revision, individualizing laboratory testing to patient clinical needs, high reliance on noninvasive monitoring, daily laboratory determination during morning rounds, utilization of clinical

triggers, high reliance on provider's critical assessment and vigilance of patients, and continuous feedback on results of the initiative at the bedside and small educational settings with valued heart center team engagement and feedback.

The cultural change was facilitated by maintaining a high profile among CICU staff and the hospital-wide zero harm initiative to regard patient safety as the top priority. Ongoing education and study results reporting served to reinforce provider reassurance and confidence that more laboratory testing did not improve care.[6] During the postintervention period, a high profile of laboratory ordering was maintained by incorporating a daily discussion during morning and evening rounds to include appropriate laboratory ordering tailored to each individual patient. Continuous collaboration was accomplished as mini PDSA cycles were implemented, staff participation encouraged, and feedback welcomed and addressed. The hospital administration and Division of Pediatric Critical Care supported the project by providing improvement systems and statistical support (**See table, Supplemental Digital Content 1, *http://links.lww.com/PQ9/A19***).

In this QI study, individual patient testing resulted in a further reduction among RACHS postintervention groups 1–2 and 5–6 over time. Most notably is the reduction in total labs/pt, labs/pt/d especially among BG and HG. Overall sustainability is likely due in part to a high reliance on noninvasive monitoring with end-tidal carbon dioxide and near-infrared spectroscopy, as well as elimination of daily CBCs. This is remarkable considering that RACHS group 5–6 represents the most complex and primarily cyanotic surgical repairs that require vigilant and close monitoring.

CLABSI and mortality to discharge remained low across all years. However, the rate of reintubation was significantly higher in postintervention patients with RACHS 3–4 procedures. In this study, the rate of reintubation reported is not necessarily equivalent to extubation failures because the institutional reporting system does not differentiate between extubation failure and the need of reintubation required for a procedure, intervention, or diagnostic test. Nevertheless after adjusting for reintubation secondary to procedures, patients with procedures RACHS 3–4, the proportion remained significantly increased, but only in this subset. Further analysis of higher reintubation rates demonstrated that neither abnormally low pH per patient nor length of total intubation differed across intervention periods or RACHS groups. Additionally, blood gas testing before extubation suggested similar clinical vigilance in the postintervention period. We cannot further explain the elevated reintubation rate in this subset.

Postintervention patients had a higher proportion of arrhythmias and abnormally low magnesium levels per patient. Arrhythmias were statistically higher in patients with RACHS 3–4 procedures. These procedures have a higher risk of arrhythmias given necessitated repair near the vicinity of the conduction system and younger age.[14–16] Given that the more severely complex patients (RACHS 5–6) did not have an increase in arrhythmias, a direct link to decreased laboratory testing cannot be drawn. A study by Delaney et al found no significant differences in magnesium and calcium levels between patient with or without arrhythmias after heart surgery.[14]

Study limitations include its performance at a single center with unique ordering processes, staffing structure, and computer system. The study did not track volume of blood loss neither from phlebotomy nor from repeated laboratory draws if samples were mishandled or altered. The total transfused blood volume was not tracked as providers' blood transfusion practices changed during the study period. The actual number of samples drawn was not tabulated, as several test panels can be run in a single draw but were counted individually by test name.

Further directions lead us toward further improvement in education regarding vigilance in magnesium evaluation and development of an automatic electronic generated report of weekly events, including abnormal labs, arrhythmias, and reintubation.

CONCLUSIONS

Following the implementation of a QI initiative, blood testing was reduced and sustained in young, complex children after heart surgery. It is unclear whether rates of reintubation and arrhythmias were significantly higher due to the complexity of this group rather than the reduction of laboratory test, but cannot be completely dismissed as an unintended consequence.

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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