RESEARCH PAPER

Optimizing Utilization of Laboratory Investigations in Neonatal Intensive Care Unit

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Objective: To optimize utilization of laboratory tests by measuring baseline rates and appropriateness of investigations, assessing the barriers to rational use, and developing and implementing an educational package for resident doctors.

Design: Quality improvement study.

Setting: Neonatal intensive care unit (NICU) from August, 2015 to December, 2016.

Participants: All neonates admitted in NICU and resident doctors working in NICU.

Intervention: Addressing barriers, educational package, posters and group discussions.

Main outcome measures: Laboratory test rates for hematology, biochemistry and blood gas. Proportion of tests judged to be inappropriate.

Results: At the baseline, median (IQR) laboratory test rate patient/day was 0.6 (0.2-1.5) and one-fifth of tests were classified as inappropriate. Mechanical ventilation and sepsis were independent predictors of laboratory test rates but could explain only 35% of the disparities, indicating variations in clinical practice. Following a short period of intervention, hematology investigations showed a trend towards reduction, though overall test rates did not change significantly.

Conclusions: Addressing barriers, creating awareness and educational interventions were able to bring down hematology laboratory test rates in a short period. A longer period of sustained intervention is required to demonstrate significant effects on test ordering behavior.

Keywords: *Biochemistry, Blood gas, Hematology, Tests*.

Increased usage of laboratory tests is appropriate if it aids in making accurate diagnosis, planning treatment, shortening hospital stay or prognostication [1]. Inappropriate laboratory utilization may include overutilization, underutilization, as well as ordering incorrect tests. This is seen more frequently in teaching hospitals [2,3]. The estimates of inappropriate laboratory testing vary greatly, though Carter gave an overall estimate of 25% in England [4]. Several studies show that routine automated laboratory tests like complete blood count and electrolyte panels are highly prone to over-utilization [5].

In developed countries, several initiatives have been introduced to reduce over-investigation and to change physician behavior to adhere to guidelines [6,7]. A systematic review suggested that educational intervention has largest reduction in tests but targeting multiple behavioral factors was more successful than single factor [8]. However, there is very little evidence related to utilization of laboratory tests in neonates.

The objectives of this study were to assess rates of laboratory testing and proportion of inappropriate tests in neonates admitted to neonatal intensive care unit (NICU), to identify barriers and facilitators for optimum utilization, followed by development and implementation of an educational package for resident doctors, and to see its impact on laboratory test rates and their appropriateness.

METHODS

This was a quality improvement (QI) initiative implemented in NICU of a tertiary-care hospital in India. The study was approved by the Institutional Ethics committee. Waiver of consent was obtained for individual patients, but informed consent was taken from individuals participating in Focused group discussions. All neonates admitted in NICU during the study period were eligible for enrolment. The study was carried out in four phases and included all tests sent to hematology, biochemistry and blood gas laboratories.

Phase 1 (Baseline survey/pre-intervention): Baseline rates of laboratory testing and their appropriateness were measured for a consecutive period of 30 days. A

structured investigation sheet was placed in each baby's clinical file. It had columns for indication for performing the test and action taken following the receipt of results. Modified NEOMOD (Neonatal multiorgan dysfunction) scoring was used to assess the level of sickness [9]. All tests were assessed for appropriateness by a review of case records by three investigators on the basis of consensus. A test was classified as inappropriate [10], if any of the following four criteria was met: (*i*) the test was not relevant to neonate's symptoms and provisional diagnosis, (*ii*) a normal result was not used to exclude suspected diagnosis *e.g.* sending CRP for suspected sepsis and giving antibiotics even if CRP was reported negative, (*iii*) previous test report was not collected/not seen before sending new one, (*iv*) the test result did not make any difference to the management and careful review of the chart and hospital course did not indicate any change in the clinical status of the patient.

Phase 2: A Focused group discussion with a group of resident doctors was conducted to understand barriers, facilitators and felt needs of residents with relation to optimal utilization of laboratory testing. Posters were developed to sensitize residents regarding optimal utilization of lab tests and blood conservation. A compact pocket booklet was developed giving relevant information about commonly performed laboratory tests in NICU. This included how to send the test, where to send, which vacutainer to use, costs and result turn-around time. Protocols for monitoring of laboratory parameters in common conditions and reference ranges of various laboratory tests were also included.

Phase 3: The educational package was implemented with help of faculty and senior residents in the form of group discussions, presentations and one-to-one discussions. Residents were encouraged to use the pocket book and feedback was collected.

Phase 4 (post-intervention): The rates of laboratory tests and their appropriateness was re-measured for a period of 10 days using the same tools as in Phase 1.

Statistical analysis: Data analysis was carried out using IBM SPSS 23.0. The rates of laboratory tests were expressed as per patient day of NICU stay. Normally distributed continuous variables were compared using *t* tests. Skewed continuous variables were compared using Mann Whitney U test. Means of multiple groups were compared using one way ANOVA. Related samples were compared using paired *t* test (when normally distributed) and Wilcoxon signed rank test (skewed data). Differences in proportions were compared using the Chi square test. Independent factors affecting the rate of laboratory tests were assessed by linear regression analysis.

RESULTS

A total of 639 tests conducted in 66 neonates in pre-intervention phase and 240 tests conducted in 34 neonates in post-intervention phase were analyzed. ***Table* I** depicts characteristics of subjects in pre- and post-intervention phases which were similar. The rates and appropriateness of laboratory tests pre- and post-intervention are shown in ***Tables* II** and **III**. The overall laboratory test rate was not different between the two phases but hematology test rates showed a trend towards significant decrease in post-intervention phase. Overall about one-fifth of tests were labelled inappropriate. Commonest reasons for tests to be labelled inappropriate were inadequate sample volume, hemolysis and sample collection in wrong container. The proportion of

TABLE I COMPARISON OF CHARACTERISTICS OF SUBJECTS IN PRE- AND POST-INTERVENTION PHASES

Characteristic	*Pre-intervention (phase 1)*	*Post-intervention (phase 4)*	*P value*
Number of patients enrolled	66	34	
Gestation (wks) (mean (SD)*	32.1 (3.4)	32.4 (3.9)	0.70
Birthweight (g), Median (IQR)#	1256 (960-1647)	1358(988-1903)	0.77
Male gender, *n* (%)	59	67	0.40
Modified NEOMODS score, median (IQR)#	1.6 (1.0- 2.4)	2.0 (1.3-3.0)	0.225
Sepsis (suspect and culture proven), *n* (%)	29	32	0.71
Continuous positive airway preesure, *n* (%)	53	44	0.39
Mechanical ventilaton, *n* (%)	15	23	0.3
Transfusion, *n* (%)	4.6	17.6	0.06
Intraventricular hemorrhage grade II and above, *n* (%)	1.5	8.8	0.07
Period of observation (d), median (IQR)#	8 (4 -15)	6 (4-10)	0.126

**t test, #Mann-Whitney U test.*

TABLE II LABORATORY TESTS PER PATIENT DAY IN PRE- AND POST-INTERVENTION PHASES

Lab tests	*Median (IQR)*		*P Value*
	Pre-intervention phase	*Post-intervention phase*	
Total	0.5 (0.2-1.5)	0.7 (0.2-1.6)	0.9
Hematology	0.1 (0.0-0.3)	0.0 (0.0-0.2)	0.05
Biochemistry	0.1 (0.0-0.3)	0.05 (0.0- 0.2)	0.3
Blood gas analysis	0.3 (0.1-0.8)	0.7 (0.1-1.3)	0.2

TABLE III PROPORTION OF INAPPROPRIATE LABORATORY TESTS IN PRE- AND POST- INTERVENTION PHASES

Lab tests	*Pre-intervention phase*			*Post-intervention phase*			*P value**
	A	IA	% IA*	A	IA	% IA*	
Total	517	122	19 %	199	41	17%	0.71
Hematology	100	21	17.3%	27	5	15.6%	0.305
Biochemistry	103	44	29.9%	23	9	28.1%	0.375
Blood gas	314	57	15.4%	149	27	15.3%	0.99

*A: Appropriate; IA: Inappropriate; *Comparison between % inappropriate tests in pre and post intervention phases.*

inappropriate tests did not change significantly in post-intervention phase.

The test rates were higher in neonates with birth weight less than 750 g and in those more than 1500 g, (P=0.12). As the modified NEOMODS score increased, the laboratory test rate also increased. The rates were higher in patients with score ≥3 (P=0.01). Test rates were similar in first 4 days of hospitalization but decreased thereafter (***Web Fig.* I**). The median (IQR) rates were higher in first 3 days of hospital stay *vs*. period beyond 3 days [0.7 (0.3-1.9) *vs* 0.6 (0.06 – 1.4), P=0.01].

Linear regression analysis including variables mechanical ventilation, sepsis, illness severity score (modified NEOMODS), birthweight and gender revealed that mechanical ventilation (β 0.299 [95 % CI 0.251-0.975]; P=0.001) and sepsis (β 0.318 [95 % CI 0.303-1.118]; P=0.001) were independent predictors of laboratory test rates. The adjusted R square was 0.349, thereby suggesting unexplained variation in laboratory test rates, indicating scope for improvement in practice.

Focused group discussion with resident doctors revealed certain barriers like problems in handover about tests done or ordered, confusion in interpretation of electrolyte reports from blood gas and biochemistry laboratory, use of CRP *vs* procalcitonin in sepsis screen etc. These were addressed in the pocket booklet and group discussions.

DISCUSSION

We studied the rates of hematological, biochemical and blood gas tests in a NICU population and found that the rates of investigations were higher in neonates with birthweight less than 750 gms and in first 3 days of hospital stay. The test rates increased with increasing illness severity. Mechanical ventilation and sepsis were independent predictors of higher rates of laboratory tests. However, these parameters could explain only 35% of the variation.

There are only limited studies available regarding the rates of investigations in NICU. Ullmann, *et al*. [11] reported comparable median laboratory test rate of 0.7 (0.4) per patient day from a tertiary care Australian NICU with similar patient profile [11]. Similar to our study, other published studies have also observed that blood gas analysis is the most common reason for sampling in NICU followed by other routine laboratory tests [2,11]. The highest proportional contribution to inappropriate tests was by biochemistry tests. The reason for frequent ordering of serum electrolytes can be due to easy availability and non-reliance on blood gas electrolyte results. Inappropriate ordering of blood gas analysis can be partly due to easy availability and partly due to the fact that indication of the test is based on clinical judgement [11].

Several systematic reviews have been published regarding the influence of educational interventions in decreasing laboratory test utilization [2,8]. A quality improvement study demonstrated significant reduction in blood gases per patient day from 8.2 to 4.8 following introduction of guidelines and regular feedback in an adult surgical ICU [12]. Merkeley, *et al*. [13] showed a decrease in use of complete blood count by 15% and electrolyte panel by 13% in a tertiary-care ICU following educational sessions for hospital staff. We could identify duplication of hematology tests as emergency reports were not giving differential counts and repeat tests were sent to the main laboratory next day. We addressed this issue by requesting emergency hematology to provide differential counts for sick neonates, whenever required, so that results can be obtained earlier and also repeat sampling can be avoided. This helped in significant reduction of hematology tests in post intervention phase. We could not demonstrate significant reduction in inappropriately ordered blood gases in the post-intervention phase. This was partly due to measurement

WHAT IS ALREADY KNOWN?

- Inappropriate laboratory investigations increase cost and blood loss, and may lead to more tests and wrong diagnosis, and cause anxiety.

WHAT THIS STUDY ADDS?

- It is possible to optimize utilization of laboratory tests by addressing local barriers and implementing an educational package.

of impact within very short time gap after intervention. It is known that interventions aimed at changing the physicians behavior need longer time-span to show effect. Participants enrolled in post-intervention phase were more sick and a higher proportion were ventilated, yet blood gas analysis rates did not increase significantly.

In conclusion, use of hematology laboratory tests in NICU could be decreased by removing local barriers, and implementing educational interventions and reminders. A longer period of sustained intervention, regular audits and improving work flows is required to show significant effects on test-ordering behavior.

Contributors: PK: conceptualization; SD, PK, SSS, VS: methodology; SD: data acquisition; SD, PK, SSS, VS: interpretation and analysis; PK, SSS, VS: supervision; PK, SSS, VS: validation; SD, PK, SSS, VS: writing, review and editing.

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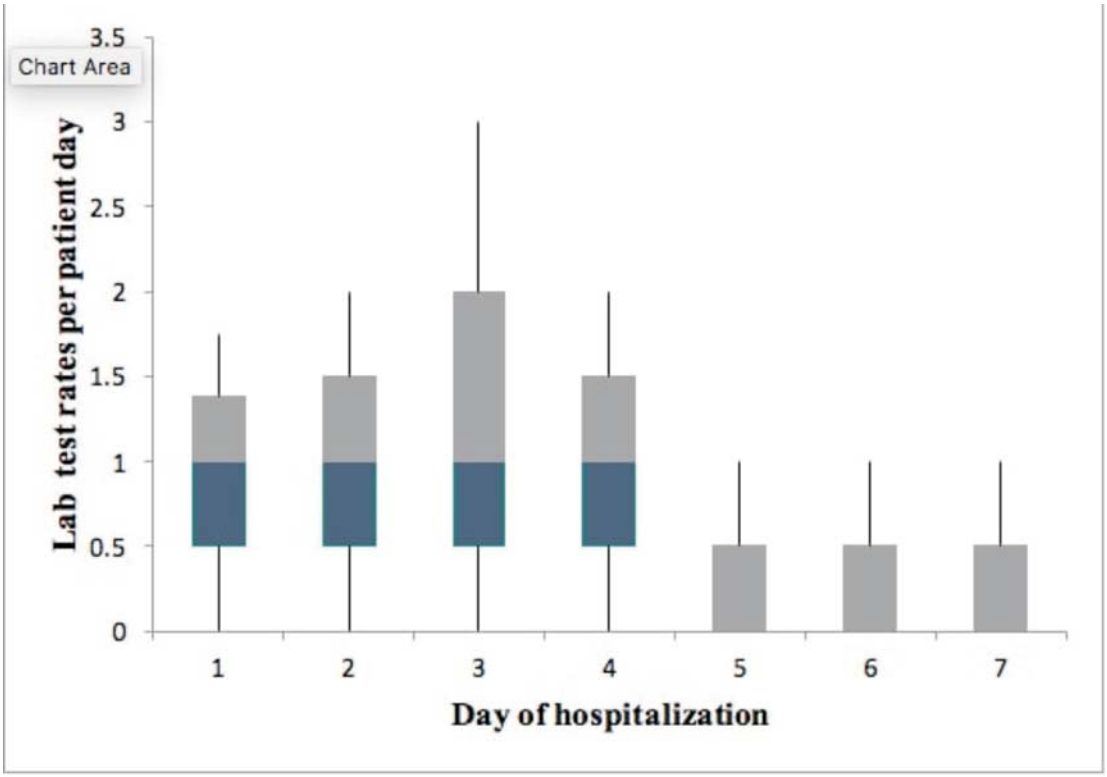
REFERENCES

1. Kwok J, Jones B. Unnecessary repeat requesting of tests: An audit in a government hospital immunology laboratory. J Clin Pathol. 2005;58:457-62.
2. Zhi M, Ding EL, Theisen-Toupal J, Whelan J, Arnaout R. The landscape of inappropriate laboratory testing: A 15-year meta-analysis. PLoS One. 2013;8:e78962.
3. Konger RL, Ndekwe P, Jones G, Schmidt RP, Trey M, Baty EJ, *et al*. Reduction in unnecessary clinical laboratory testing through utilization management at a US government veterans affairs hospital. Am J Clin Pathol. 2016;145:355-64.
4. Fryer AA, Smellie WSA. Managing demand for laboratory tests: A laboratory toolkit. J Clin Pathol. 2013;66:62-72.
5. Krasowski MD, Chudzik D, Dolezal A, Steussy B, Gailey MP, Koch B, *et al*. Promoting improved utilization of laboratory testing through changes in an electronic medical record: Experience at an academic medical center. BMC Med Inform Decis Mak. 2015;15:11.
6. National Institute for Health and Care Excellence (NICE). Cost-saving Guidance. Available from: *https://www.nice.org.uk/about/what-we-do/into-practice/cost-saving-guidance*. Accessed November 16, 2017.
7. Morden NE, Colla CH, Sequist TD, Rosenthal MB. Choosing wisely – The politics and economics of labeling low-value services. N Engl J Med. 2014;370:589-92.
8. Kobewka DM, Ronksley PE, McKay JA, Forster AJ, van Walraven C. Influence of educational, audit and feedback, system based, and incentive and penalty interventions to reduce laboratory test utilization: A systematic review. Clin Chem Lab Med. 2015;53:157-83.
9. Cetinkaya M, Köksal N, Özkan H. A new scoring system for evaluation of multiple organ dysfunction syndrome in premature infants. Am J Crit Care. 2012;21:328-37.
10. Robinson A. Rationale for cost-effective laboratory medicine. Clin Microbiol Rev. 1994;7:185-99.
11. Ullman AJ, Keogh S, Coyer F, Long DA, New K, Rickard CM. "True Blood" The critical care story: An audit of blood sampling practice across three adult, paediatric and neonatal intensive care settings. Aust Crit Care. 2016;29:90-5.
12. Merlani P, Garnerin P, Diby M, Ferring M, Ricou B. Quality improvement report: Linking guideline to regular feedback to increase appropriate requests for clinical tests: Blood gas analysis in intensive care. BMJ. 2001;323:620-4.
13. Merkeley HL, Hemmett J, Cessford TA, Amiri N, Geller GS, Baradaran N, *et al*. Multipronged strategy to reduce routine-priority blood testing in intensive care unit patients. J Crit Care. 2016;31:212-6.



WEB FIG. I *Laboratory test rates (per patient day) according to day of hospitalization.*