A Computer Based Intervention on the Appropriate Use of Arterial Blood Gas

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Objective: *To evaluate impact of a computer-based intervention on arterial blood gas (ABG) usage in an intensive care setting.*

Design: *Retrospectively examined, via mixed group analysis, the effects of the intervention on ABG usage in the intensive care unit (ICU).*

Subjects: *Included all clinicians who placed ABG orders in an ICU using the computerized physician order-entry system, as well as controls in non-order entry units.*

Methods: *Computer-based intervention presenting ordering clinician with patient's previous ABG values and limiting forward duration of tests ordered. Study spanned 12 weeks, 5 weeks pre-intervention and 7-weeks post-intervention. Of 8 ICUs, intervention implemented in 6, not implemented in 2. Data analyzed using the repeated measure ANOVA.*

Results: *Physicians entered <40% ABG orders. 376 ABGs per week processed pre-intervention, 387 per week post. Results nonsignificant with a p= 0.09. Orders placed declined from 1039 per week, Jan 2000 to 662 per week, April 2001.*

Discussion: *Study did not demonstrate significant change; limited power. Need longer study periods. Impact improved in the future by targeting physician users and tailoring intervention to specific work flow pattern of high utilization units.*

BackgroundThe arterial blood gas (ABG) is a frequently ordered lab test. The vast majority of ABG orders are placed on critically ill and ventilated patients in intensive care units. The advent of noninvasive monitoring methods, namely pulse oximetry, have markedly reduced the indications for arterial blood gas analysis (1). The continued frequency of ABG valuation, particularly in the intensive care setting, may be influenced by routine work-patterns and easy access via arterial lines (2). Reports have suggested that much of the data generated by laboratory tests are redundant and often have little effect on treatment. Bates et al. examined a series of clinical tests, including ABGs, and found that many common tests are repeated too early to provide useful clinical information (3).

Previous studies have demonstrated that ancillary expenditures in the intensive care setting can be decreased without compromising care. Implementation of practice guidelines for blood gas measurement has been shown to decrease test utilization without affecting outcome (4); however, in a setting such as the intensive care unit wherein multiple physicians with rotating schedules participate in patient care, familiarity with and adherence to formal guidelines is often low. A study by Tierney et al. revealed that presenting physicians with previous test results at the time of order entry in an outpatient setting resulted in a significant reduction in the ordering of laboratory tests (5).

We postulated that in an ICU setting a similar strategy might influence ABG measurement. To test this hypothesis the institution's resource utilization committee, in conjunction with the Department of Biomedical Informatics designed, implemented, and examined a computer-based intervention in which initiation of an ABG order using the hospital's physician order-entry system triggered a screen that provided the ordering clinician with educational text alongside a graphical display of the patient's previous ABG values and O_2 saturations. By this method, advance ordering of ABGs was limited to within 24hours so no multi-day orders were allowed post-intervention. In this preliminary study, we examined the effects of the intervention on ABG ordering patterns in the ICU. This intervention was part of a larger ongoing cost containment initiative at our institution.

Methods

Study Site

Vanderbilt University Medical Center is a 630-bed university hospital with 31,000 admissions per year. Physicians write orders using a computerized provider order-entry (POE) application (6). Interns and residents enter the vast majority of all patient orders; however, respiratory therapists, nurses and medical receptionists also have the capability of entering protocol-based, verbal, or written orders from physicians. Study participants consisted of all individuals with the authority to enter orders via the computerized order entry system.

The 8 ICUs are divided into the trauma, general surgical, medical, cardiac, burn, neurology, pediatric and neonatal units. POE is implemented in all ICUs except the neonatal and pediatric units.

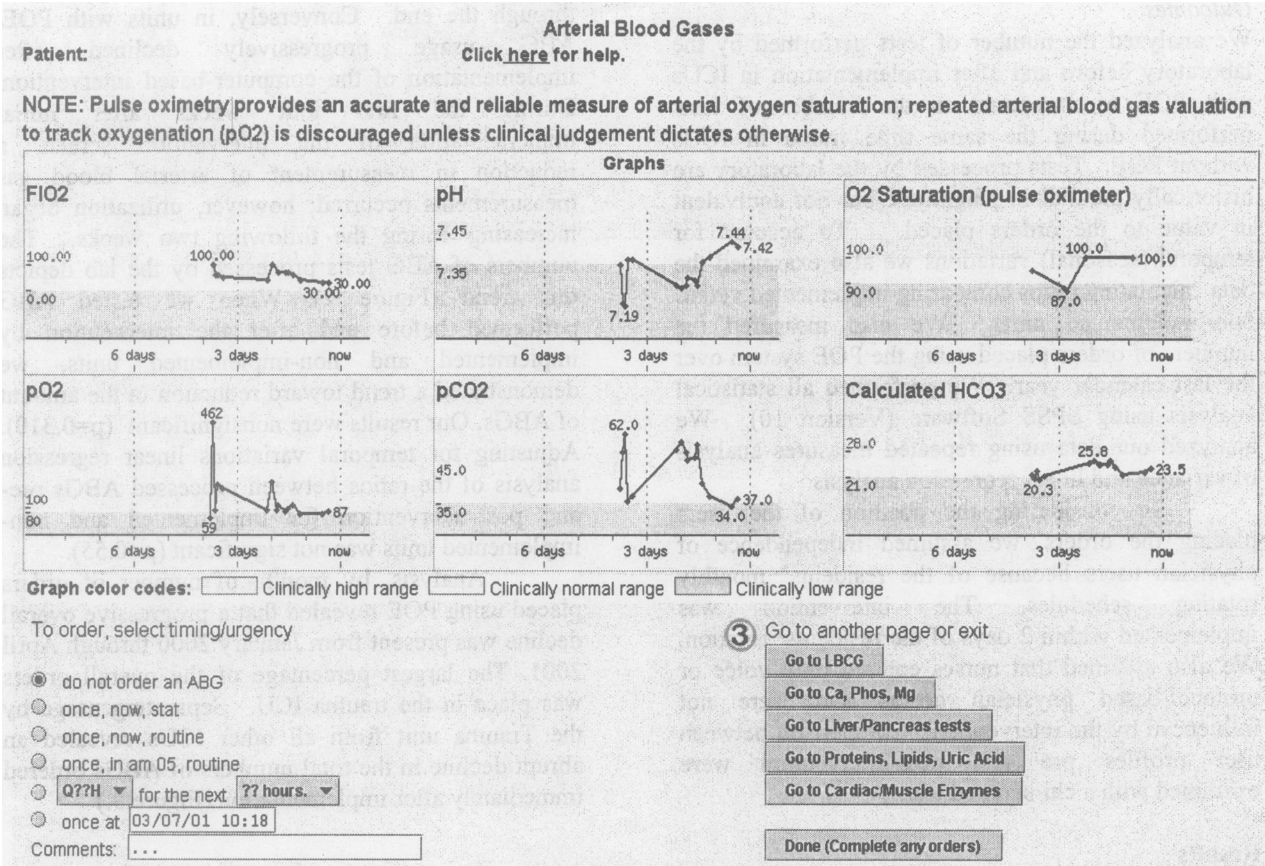

Figure 1: Intervention Screen displayed during post-intervention period.

Design

We utilized a mixed-group design to retrospectively analyze the impact of this computer-based intervention on physician ordering behavior. The intervention was implemented throughout the hospital; however, the ICUs were the target study sites. With ventilated patients and frequent standing orders for serial measurement, ICUs are the areas with the highest volume ABG utilization. Non-implemented ICUs served as the concurrent control group in both study periods.

The pre-intervention period spanned 5 weeks (Nov 1, 2000 to Dec 5, 2000). The post-intervention period spanned 7 weeks (Dec 6, 2000 to Jan 23, 2001).

During the intervention period, when a user initiated an ABG order, the ordering program opened a web page on the screen. This screen displayed educational text alongside the recorded results, in graphical format, for the patient's most recent arterial blood gas and O_2 saturation measurements (Figure 1).

Ordering serial ABGs for a period greater than 24hours was not allowed due to restrictions on ordering imposed by the web page. Otherwise, we placed no formal constraints on the clinician's ability to place an ABG order; however, the default (pre-populated) response was to cancel the order. Final decision to test or not was left to the user's discretion.

The intervention screen displayed six graphs: pO_2, pCO_2, HCO_3, O_2 saturation, pH, and F_iO_2 (Figure 1). All values, except O_2 saturation, reflected previous ABGs performed during the patient's current hospitalization per a query of the hospital's lab database. The SpO_2 values appeared as recorded by ICU personnel within the hospital's respiratory therapy system and transferred to the clinical repository. Areas on each graph shaded in pink indicated abnormally high values; areas in blue revealed abnormally low values; areas in between indicated normal range.

Outcomes

We analyzed the number of tests performed by the laboratory before and after implementation in ICUs with POE as compared to the number of tests performed during the same time frame in ICUs without POE. Tests processed by the laboratory are historically parallel in magnitude but not equivalent in value to the orders placed. To account for temporal (seasonal) variations we also examined the data calculating ratios comparing implemented versus non-implemented units. We also measured the numbers of orders placed using the POE system over the last calendar year. We performed all statistical analysis using SPSS Software (Version 10). We analyzed our data using repeated measures analysis of variance and linear regression analysis.

In considering the position of the users placing the orders, we assumed independence of physician users because of the residents' monthly rotating schedules. The intervention was implemented within 2 days of the residents' rotation. We also assumed that nurses entered only voice or protocol-based physician orders and were not influenced by the intervention. Comparison between user profiles pre and post-intervention were examined with a chi-squared test.

Results

During the 5-week pre-intervention period, the lab processed an average of 269 ABGs per week from implemented units. In post-intervention period, an average of 387 ABGs per week were processed. During both periods, 74% of all ABG orders were placed in ICUs. ABG utilization in ICUs without POE progressively increased from the beginning through the end. Conversely, in units with POE, ABG usage progressively declined after implementation of the computer-based intervention. During the first four weeks after initial implementation of the intervention screen, a reduction in measurement of arterial blood gas measurements occurred; however, utilization began increasing during the following two weeks. The numbers of ABG tests processed by the lab depicts this trend (Figure 2). When we tested ABG performed before and after the intervention by implemented and non-implemented units, we demonstrated a trend toward reduction in the amount of ABGs. Our results were nonsignificant ($p=0.310$). Adjusting for temporal variations linear regression analysis of the ratios between processed ABGs pre- and post-intervention for implemented and non-implemented units was not significant ($p=0.55$).

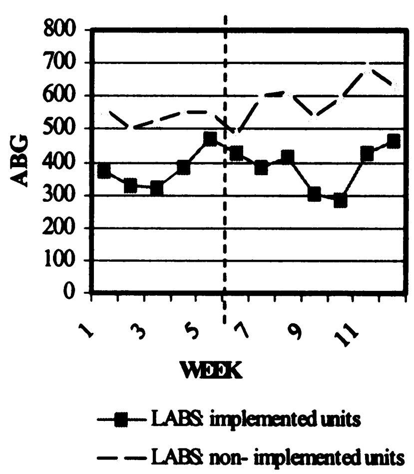

Figure 2: Comparison of numbers of ABGs performed in the intervention and comparison groups. Dotted line indicates implementation.

Analysis, by month, of number of orders placed using POE revealed that a progressive overall decline was present from January 2000 through April 2001. The largest percentage of the overall orders was place in the trauma ICU. Separating usage by the Trauma unit from all other ICUs revealed an abrupt decline in the total numbers of ABGs ordered immediately after implementation (Figure 3.)

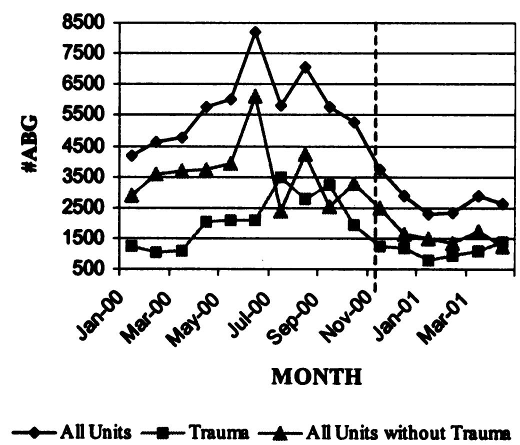

Figure 3: ABG orders placed over calendar year. Dotted line indicates implementation

Table 1 displays the percentage of orders placed by each category of user. Physicians placed fewer than 40% of the orders. Nurses, respiratory therapists, ancillary personnel and medical receptionists placed the majority of orders. An analysis of user distribution, using chi-square analysis, demonstrates variation between the pre- and post-intervention groups ($p<0.005$). More physicians placed orders in the post-intervention period.

In this preliminary analysis, we did not standardize results for variations in practice, standards, patient population, acuity, volume, or ventilator days amongst the different ICUs.

Table 1: Distribution of Users Placing Orders Pre and Post-Intervention

LEVEL	PRE		POST	
Ancillary staff	24	(1.8%)	15	(1.2%)
Physicians	366	(28.0%)	428	(35.4%)
Other users	8	(0.6%)	26	(2.1%)
Nurses	813	(62.0%)	670	(55.0%)
Respiratory therapy	80	(6.1%)	61	(5.0%)

Discussion

The goal of ancillary cost reduction is to improve patterns of resource utilization thereby promoting cost effective, quality care. Approximately 30% of inpatient expenditures occur in ICUs (5). The cost of reagents to analyze an ABG test at our institution is $6.69 and the charge for blood drawing, supplies, handling, and interpretation $154. This study is a preliminary examination of the impact of a computer-based intervention on ABG usage in the ICU.

Our intervention was part of a larger hospital-wide cost containment initiative. As part of this initiative, several other ancillary tests such as the basic metabolic panel were targeted with similar interventions. Additionally, faculty and staff attended educational sessions on resource utilization. The observed decline in ABG ordering frequency, therefore, in part, reflects a general downward trend in test ordering. This trend is exemplified by the progressive decline in ABG orders observed prior even to our intervention. The trend continued post-intervention with the nadir of blood gas sampling frequency occurring in the immediate post-intervention period. At this time, it is not clear if the intervention contributed to the decline. Regression analysis did not reveal a significant change; however, the power in this preliminary study is limited given the short study periods.

A desirable effect was observed during the initial 4-weeks after intervention where a distinct decrease in the number of ABG labs processed by the lab was noted in implemented units. In comparison, usage in non-implemented units continued to increase. This result suggests the intervention impacted user behavior. It remains unclear why utilization in implemented units increased during the final two weeks of the study. From this perspective our preliminary results must remain inconclusive and requires the extension of study periods.

A significant limiting factor was the large number of orders placed by non-physician users (nurses, medical receptionists, and respiratory therapists) who have limited decision-making authority. The vast majority of arterial blood gases are ordered in the surgical intensive care units (trauma, general surgical, and burn) where physicians are often in the operating room and telephone/verbal orders predominate. Hence, the target audience, the ordering physician does not interact with the screen. However, more targeted users, physicians, were exposed to the intervention in the post-implementation period as compared to the pre-implementation period.

The mixed-group study design precludes a direct correlation between the intervention and ordering frequency. Furthermore, in this preliminary study, we did not normalize for ventilator days in each unit and the study periods coincided with the winter holiday season, traditionally a time of lower ICU volume.

Despite these limitations, the results of this preliminary analysis are promising. The lowest historical values of blood gas sampling frequency occurred during the immediate post-intervention period. Although the actual difference between the implemented and non-implemented units in our preliminary analysis did not demonstrate a significant change, if the trend continued we would expect to achieve sufficient power to detect significant differences with several more months of follow up. This likelihood is exemplified by our preliminary examination of actual orders placed where a stepwise decline in the numbers of ABGs ordered is evident immediately post- intervention. The results are somewhat skewed by the large numbers of orders placed in the trauma ICU; however, consideration of the other units excluding the trauma units reveals a marked post- intervention decline. We conclude that displaying past results at the time of order entry is a valuable means of augmenting information and can be effective at decreasing over-utilization. The impact could perhaps be improved in the future by specifically targeting physician users as well as taking the individual work flow needs of each unit into account in future versions of the intervention.

Table 2: Number of ABGs processed by laboratory per unit pre and post-intervention.

IMPLEMENTED UNITS

Unit	Week												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Trauma	155	123	139	141	205	198	167	187	125	144	130	161	1875
Neurology	28	30	21	25	39	53	37	52	44	28	14	34	405
Surgery	126	128	122	176	180	90	100	92	80	80	179	148	1501
Cardiac	24	14	12	15	13	4	14	8	5	3	10	8	130
Medicine	14	9	12	25	22	45	37	32	14	19	33	33	295
Burn	28	23	16	5	14	35	29	47	34	14	61	83	389
Total	375	327	322	387	473	425	384	418	302	288	427	467	4595

NON-IMPLEMENTED UNITS

Unit	Week												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Neonatal	253	193	205	245	239	209	256	354	269	197	246	291	2957
Pediatric	314	309	325	305	316	276	344	258	272	399	445	342	3905
Total	567	502	530	550	555	485	600	612	541	596	691	633	6862

Acknowledgements

The authors wish to thank Dr. Gordon Bernard and the resource utilization committee for their contributions to this work. Dr. Miller's efforts were supported in part by NLM grant R01-LM-06226.

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