The Effect of Arterial Lines on Blood-Drawing Practices and Costs in Intensive Care Units*

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Study objective: To determine whether the presence of an indwelling arterial access line leads to differences in blood-drawing practices and costs, in patients with similar APACHE II scores, in the ICU.
Design: Prospective, observational.
Setting: Adult surgical and medical ICUs at a large military tertiary care hospital.
Patients: Twenty-five adult (*ie*, above 18 years old) patients with arterial access lines and 25 adult patients without arterial access lines. Each had APACHE II of 9 to 20 and none had any central venous access.
Measurements and results: A survey of the arterial line blood-drawing habits of critical care nurses at our hospital revealed a 2.99-mL mean discard blood volume to clear an arterial line, with only 9.4% not discarding any blood. For each patient enrolled in the study, the number of blood tests and blood draws were recorded during the first two 24-h periods after admission to the ICU. The amount of blood required by the laboratory for each blood test was totalled. In the arterial line group, the mean discard volume was added to the total for each blood-drawing procedure.
Increases were found in the number of blood tests (29% increase, p=0.013), blood-drawing procedures (30% increase, p=0.014), and the amount of blood volume (44% increase, p<0.001) sent from patients with arterial lines compared to those without.
Conclusion: When APACHE II scores are similar, the presence of an arterial access line may lead to increased blood drawing from patients in ICUs.

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APACHE II=Acute Physiology and Chronic Health Evaluation Score II

Key words: arterial lines; blood loss; blood tests; costs; critical care; phlebotomy

On admission to a hospital, patients are often subjected to phlebotomy three to four times per day for numerous blood tests. This can result in increased hospital costs and the loss of significant amounts of blood. Concern about rising hospital costs has received increased attention both in the medical literature and in the lay press. This is especially true in the ICU. In the ICU, arterial access lines can make phlebotomy easier and less painful for patients. With this ease of phlebotomy has come a perceived tendency toward ordering frequent blood tests by physicians, sending frequent blood specimens by nurses, and asking for resubmitted samples by the laboratory. This might lead to significant increases in the cost of a stay in the ICU. Arterial lines also require removing additional amounts of blood to obtain an adequate sample. The amount of blood drawn can be impressive and can result in the need for blood transfusions.[1]

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The goals of this study were, in patients with similar APACHE II scores, as follows: (1) to determine how many blood tests are sent from patients with arterial lines compared to those without; (2) to determine how many phlebotomy procedures are performed on patients in each group; and (3) to determine the quantity of blood drawn from patients in each group.

Methods and Materials

The study was approved by the Clinical Investigation Committee and the Human Use Committee/Institutional Review Board at Walter Reed Army Medical Center, Washington, DC. Because the study intended to observe the phlebotomy practices of the medical and nursing staff in our ICUs, only the investigators, the head ICU nurses, and the above committees were aware that the study was being conducted. Because the study was purely observational and involved no alteration of patient care, the need for a patient consent form was waived.

The study was conducted in two stages. During the first stage, a questionnaire was distributed to all critical care nurses concerning their practices when drawing blood via arterial lines. The data were used to obtain an average amount of blood drawn by the nursing staff to clear arterial lines prior to sample collection and allow for a more accurate estimation of blood loss totals. We utilized a questionnaire because we believed that a single ques-

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tion in a survey would generate more reliable responses than direct observation and documentation, which could introduce unmeasurable bias as our staff worked with the knowledge that they were being monitored. We repeated the same survey 24 months later to ensure consistency.

All adult patients admitted to the surgical or medical ICUs with admission APACHE II scores of 9 to 20 were eligible for the second stage of the study. The patients were placed into groups according to whether they had an indwelling arterial line in place within the first 6 h after admission to the ICU. If an arterial line was placed or removed after this initial period, the patient was removed from the study. If the patient had a central line placed during the study period, he or she was removed from the study. This was intended to eliminate the confounding factor of additional vascular access and allow determination of the impact of arterial lines only. All patients were studied for the initial 48 h of their ICU admission. We looked at 25 consecutive patients in each group.

Data were obtained for each patient by reviewing the computer entries for the total number, type, and time of each blood test recorded during each of two consecutive 24-h periods. The estimated daily blood loss was then calculated in the following manner: each test entered into the computer had the amount of blood required by the laboratory added to the total.[2] For example, each complete blood cell count, chemistry, and coagulation study was sent routinely in a 2.5-mL pediatric tube and was added to the total as such. In the arterial line group, the average amount of blood discarded to clear the line prior to sample collection, as determined by the survey, was added to the blood volume total for each phlebotomy procedure. All specimens entered into the computer within 1 h of one another were considered to have come from the same blood draw and thus constituted one procedure.

The cost of the blood tests to patients was obtained from data received from a local tertiary community hospital.

The data for the number of blood tests per patient per day, volume of blood per patient per day, and number of individual blood-drawing procedures per patient per day were collected, compared, and analyzed. Student's t test were used to compare mean values for the various groups.

Results

During the study period of May 1992 to April 1993, the admission APACHE II scores of all patients admitted to the surgical and medical ICUs were reviewed. Patients with a score of 9 to 20, without a central venous access line, who stayed in the ICU for more than 48 h were enrolled. Patient enrollment continued until each group reached 25 patients.

Fifty-three of a total of 61 critical care nurses, staffing our ICUs, responded to the survey (87%). The mean amount of blood discarded to clear an arterial line was 2.99 mL (SD, 1.40 mL; range, 0 to 6 mL). Only 5 of the 53 respondents (9.4%) did not discard blood when clearing the lines. The repeated survey 24 months later revealed similar results (mean, 2.89 mL; SD, 1.85 mL; range, 0 to 7 mL; 9.8% did not discard blood).

The arterial line and nonarterial line groups were similar with respect to age and APACHE II score (Table 1). There were 14 male and 11 female patients in the arterial line group, and 20 male and 5 female patients in the nonarterial line group. However, male and female patients had similar ages and APACHE II scores (Table 2). There was a wide variety of diagnostic categories in the two groups (Table 3).

During the first 24-h period after ICU admission, the arterial line group had a highly suggestive, but not statistically significant, increase in the number of blood tests sent to the laboratory compared with the nonarterial line group. However, during the second

Table 1—*Comparison of Patients in the Arterial and Nonarterial Line Groups (Mean ± SD)**

	Arterial Line	Nonarterial Line	Percent Difference	p Value
No.	25	25		
Age, yr	54.0 ± 20.4	63.0 ± 14.6		0.081
APACHE II	14.6 ± 3.5	13.5 ± 3.2		0.246
No. of blood tests				
1	18.0 ± 9.9	13.3 ± 6.5	26	0.055
2	11.0 ± 6.8	7.3 ± 3.3	34	0.018
T	29.0 ± 14.0	20.6 ± 8.2	30	0.013
No. of procedures				
1	8.1 ± 4.7	5.8 ± 2.8	28	0.048
2	5.0 ± 2.8	3.4 ± 1.5	32	0.012
T	13.1 ± 6.8	9.2 ± 3.4	30	0.014
Volume of blood, mL				
1	70.9 ± 37.2	42.4 ± 22.1	40	0.002
2	43.5 ± 24.4	22.0 ± 11.6	49	<0.001
T	114.7 ± 53.9	63.6 ± 28.4	44	<0.001

*1=first 24-h period; 2=second 24-h period; T=total over 48 h.

Table 2—*Demographics of Male and Female Patients (Mean ± SD)*

	Patients		
	Male	Female	p Value
No.	34	16	
Age, yr	56.4 ± 17.7	62.9 ± 18.8	0.255
APACHE II	13.8 ± 3.3	14.5 ± 3.6	0.528

Table 3—*Diagnostic Categories of Patients in the Arterial and Nonarterial Line Groups**

	Arterial Line	Nonarterial Line	Total
Respiratory insufficiency	6	12	18
Ventilated	6	5	11
Nonventilated	0	7	7
Sepsis (all sources)	6	1	7
GI bleed	3	6	9
Postoperative Neurosurgery	6	2	8
Cardiovascular	2	6	8
Unstable angina	1	3	4
Congestive heart failure	1	1	2
Arrhythmias	0	2	2
Trauma	2	1	3
Diabetic ketoacidosis	1	1	2
Other postoperative	5	1	6

*Numbers depicted (59) exceed total number of patients (50) because of multiple diagnoses.

24-h period, and when the total amounts were reviewed, statistically significant differences were seen. The presence of an arterial line increased the number of blood tests sent to the laboratory by 29% during the study period.

When the number of blood-drawing procedures performed on the patients was evaluated, we also found statistically significant differences. The patients in the arterial line group had a consistently higher number of phlebotomy procedures performed each day. There was a 30% increase in procedures in the group with an arterial line (Table 1).

Finally, there was also a statistically significant difference in the quantity of blood drawn from patients in the two groups (Table 1).

Discussion

Controlling the spiraling costs of health care has become a national priority. Since ICUs account for up to 28% of total hospital costs, they are a natural target of cost control strategies.[3] In our study, when APACHE II scores were similar, the presence of an arterial access line led to an increase in the number of blood tests by 29%, an increase in the number of blood drawing procedures by 30%, and an increase in the amount of blood volume taken from the patient by 44%. If true, these results may support surveys that 50 to 60% of blood tests may be inappropriate.[4] Other studies indicate that 85% of physicians believe that their colleagues order too many tests.[5]

Although the actual per-test cost may appear small in the spectrum of hospital costs, the cumulative effect is great. Laboratory costs make up 25% of total hospital costs, a figure that is increasing by 15% annually.[4,6] The most common additional test in the arterial line group, in our study, was the arterial blood gas, which is charged to the patient at up to $75.25 per test. The next most common additional tests were complete blood cell counts, which cost the patient up to $24.56, and chemistry profiles, which cost the patient $21.23. The average cost of the additional blood tests sent to the laboratory simply because an arterial line was in place would be approximately $500 in the first 48 h of an ICU stay.

Why are we sending so many blood tests? Even the nonarterial line group had a mean of 20.6 different tests sent over the first 48 h of an ICU stay. One reason is the increased availability of tests. In 1960, the average hospital laboratory offered 75 different tests. Today, that figure is doubled.[6] Other reasons are to reassure the medical staff and patients, to monitor the progress of treatment, and in some institutions to generate income.[7] All of these issues were compounded, in our study, by the presence of an arterial line, which made phlebotomy appear easier and of less consequence.

Concern over significant blood loss secondary to phlebotomy has been present for years. In 1971, Buckley-Sharp[7] concluded that these losses could contribute to anemia in adults. To our knowledge, our study is the first to look at the effect of arterial lines when APACHE II scores are similar. Our blood volume results fall within the range of amounts seen in previous studies.[1,8-10] Patients receiving critical care are a group that may not be able to tolerate unnecessary blood loss. Over the 48 h of our study alone, patients with arterial lines had a mean of 51.1mL of additional blood taken. If this trend continued throughout an ICU stay, the increased amount of blood loss could adversely effect outcome or expose patients unnecessarily to the risk of blood transfusions. This seems to support data from Smoller and Kruskall[10] that indicated that patients in an ICU with arterial lines had three times the amount of blood loss due to phlebotomy and two times the number of blood draws compared to those without. In their study, however, no attempt was made to correct for the degree of illness and whether those with arterial lines were simply sicker and required more frequent blood tests.[10]

We attempted to control for illness severity by looking at APACHE II scores and diagnoses between the two groups. APACHE II is currently one of the most widely utilized and reproducible monitors to compare illness severity within ICU patient populations. There were differences in the diagnostic categories of the patient groups that could, in part, account for the results seen (Table 3). Overall, however, they were not of a pattern that would confound the observed results. For example, the nonarterial line group had larger numbers of patients with respiratory insufficiency and gastrointestinal bleeds. These patients would be expected to require more frequent blood draws. There was also an increased number of postoperative neurosurgical patients in the arterial line group despite the expectation that they would not require many blood draws.

Most additional blood loss from the arterial line group came from discarding blood to clear the line. This reinforces the need to implement blood conservation techniques, as advocated by Chernow et al[11] and others.[12-14] At our hospital, we have not yet utilized in-line blood conservation devices. Had we done so, up to 31% of the blood loss might have been avoided.

Potential limitations of our study included the fact that the arterial line group consisted of 21 patients in the surgical ICU and 4 patients in the medical ICU (86% surgical ICU), while the nonarterial line group contained 11 patients in the surgical ICU and 14 patients in the medical ICU (44% surgical ICU). Looking at the subgroup of only patients in the surgical

Table 4—*Comparison of Patients in the Surgical ICU in the Arterial Line and Nonarterial Line Groups (Mean ± SD)**

	Arterial Line	Nonarterial Line	Percent Difference	p Value
No.	21	11		
Age, yr	56.0±21.1	59.0±16.4		0.656
APACHE II	13.9±3.2	13.7±3.8		0.897
No. of blood tests				
1	15.9±8.0	9.3±4.0	42	0.004
2	9.3±4.7	6.1±2.1	34	0.013
T	25.1±9.1	13.4±5.2	47	0.001
No. of procedures				
1	6.8±2.3	4.7±2.0	31	0.014
2	4.2±2.1	3.1±1.2	26	0.064
T	11.0±3.3	7.8±2.2	29	0.003
Volume of blood, mL				
1	61.2±25.1	28.3±15.4	54	<0.001
2	36.2±16.2	17.8±6.5	51	<0.001
T	97.7±31.3	46.1±18.1	53	<0.001

*1=first 24-h period; 2=second 24-h period; T=total over 48 h.

ICU in the arterial and nonarterial line groups allowed us to determine if differences in patients in medical and surgical ICUs explained our results. Since most patients in the surgical ICU had their decisions about arterial lines made in the operating room by a physician uninvolved in the ICU care, it also allowed us to eliminate some possible selection biases. We found that our data remained statistically significant in all categories, with the exception of the number of procedures performed during the second 24-h period ($p=0.064$) (Table 4). In addition, the survey to determine the amount of discarded blood and our usage of computer entries to determine the number of blood-drawing procedures are also potential limitations and may not have reflected daily variations in individual practice habits and staffing patterns. They were necessary, however, to avoid the bias inherent when providers are aware that they are being monitored. Our figure of 31% of the total blood loss being secondary to discard practices compares favorably with the figure of 26% found by Smoller and Kruskall.[10]

It is incumbent on those who work in ICUs to reexamine their own practices. Our study indicates that a tendency may exist to increase blood tests, phlebotomy procedures, and blood loss when arterial lines are in place.

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