Improving the Accuracy of Kt/V Measurement: The Role of the Technician

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Background. *Accurate post-dialysis blood sampling is necessary to correctly measure hemodialysis dose (Kt/V). We sought to examine errors in post-dialysis blood sampling.*

Methods. *We examined all treatments with a pre- and post-dialysis urea determination among 117 patients cared for by 27 technicians over a 7-month interval at a single dialysis facility. Because errors in post-dialysis blood sampling typically result in overestimation of delivered Kt/V, we labeled as probable measurement errors any treatments in which delivered Kt/V exceeded prescribed Kt/V by 25% or more.*

Results. *Of 749 total treatments, 24 (3%) had probable measurement errors. The error rate was 8% for treatments with a blood flow rate < 360 ml/min ($p < 0.01$). Other patient and treatment characteristics were not independently associated with error rate. The 27 technicians varied greatly in their error rate, with a range from 0% to 28%. Four technicians, with error rates of 12–28%, were significantly different from other technicians even after adjustment for blood flow rate. Probable measurement error was independently associated with receiving treatment from these specific technicians (odds ratio 5.5, $p < 0.001$) and with a treatment blood flow rate < 360 ml/min (odds ratio 13.8, $p < 0.001$). The same four technicians were identified as outliers under alternate definitions of probable measurement error.*

Conclusions. *Probable errors in post-dialysis blood sampling occur in an appreciable proportion of treatments. Much of the variation in error rate is related to specific personnel. Efforts to monitor and educate facility personnel on post-dialysis blood sampling may improve the accuracy of hemodialysis dose calculations.*

Delivering an adequate hemodialysis dose (Kt/V) is an important determinant of patient survival.[1-3] Accurate post-dialysis blood sampling is necessary to correctly measure hemodialysis dose.[4] However, previous studies have documented wide variation in blood sampling techniques across facilities.[5,6] As part of a local quality improvement process, we sought to determine how often errors in post-dialysis blood sampling occur and to examine patient, treatment, and technician correlates of such errors.

Methods

Patients

All patients at a single, freestanding hemodialysis facility in northeast Ohio were eligible for analysis. For each patient, we recorded age, race, gender, cause of renal failure, and height from chart abstraction.

Treatments

From January 1, 2001, to July 30, 2001, we monitored all treatments for which there were pre- and post-dialysis blood urea nitrogen determinations. These "measured treatments" generally occurred once a month. For each such treatment, we obtained the pre- and post-dialysis blood urea nitrogen, post-dialysis weight, ultrafiltration volume, actual treatment time, actual blood flow rate, actual dialysate flow rate, dialyzer type, and type of vascular access.

A protocol for appropriate blood sampling at our facility has been in place for five years and is as follows:

1) Dialysis machine ultrafiltration should be turned off or decreased to its lowest rate. Dialysate flow should likewise be turned off or set to bypass.
2) Patient blood pump speed should be turned to 50–100 ml/min.
3) Allow 15–20 seconds to pass.

4) Blood sample should be drawn from the arterial line for 20–30 seconds after blood pump speed is decreased, but no later than 30 seconds after.
5) Any samples not drawn by this protocol should be discarded and the pre/post BUN sample should be repeated at the next Monday or Tuesday dialysis session.
6) During the last 15 minutes of dialysis, if >250 ml of normal saline was given, or if large changes in blood flow or dialysate flow occurred, the post-dialysis BUN draw should be postponed until the next treatment.

Technicians

For each measured treatment, we recorded the initials of the technician who collected the post-dialysis blood sample for the BUN determination. In addition, we tabulated the total number of treatments (measured and unmeasured) delivered by each technician over the 7-month observation period. Because of a policy requiring a rotating schedule, technicians are assigned different patients every month.

Statistical Analysis

For each treatment, we calculated delivered Kt/V using the Daugirdas II formula.[7] We calculated prescribed Kt/V based on manufacturers' specifications for the prescribed dialyzer at the actual blood and dialysate flows of each treatment, and for the actual treatment time. Patient anthropometric volume (V) was calculated based on patient- (height, weight) and disease-specific characteristics, using a validated formula.[8]

Because errors in post-dialysis blood sampling typically result in overestimation of delivered Kt/V,[4] we labeled as probable measurement errors any treatment in which delivered Kt/V exceeded prescribed Kt/V by 25% or more. We used the chi-square test, Fisher's exact test, or the *t*-test to examine the univariate relationship between measurement error and patient, treatment, and technician characteristics. We used logistic regression to further examine predictors that were significant on univariate analysis. As part of a sensitivity analysis, we examined alternate definitions of probable measurement error. In these sensitivity analyses, we labeled as probable measurement errors treatments in which delivered Kt/V exceeded prescribed Kt/V by 10% or by 33%.

Table I. Characteristics of patients, treatments, and technicians.

Patient Characteristics (n = 117)	
Mean age (yr)	55
Race (%)	
black	53
white	46
other	1
Male (%)	53
Cause of renal failure (%)	
hypertension	40
diabetes	39
other	21
Mean patient volume (L)	43
Measured Treatment Characteristics (n = 749)	
Dialyzer type & manufacturer (%)	
F-80 (Fresenius)	86
CT-190 (Baxter)	10
F-70 (Fresenius)	3
Access type (%)	
graft	56
fistula	26
catheter	18
Mean blood flow (ml/min)	378
Mean treatment duration (min)	220
Technician Characteristics (n = 27)	
Total treatments provided (mean)	362
Measured treatments provided (mean)	28

Results

Patient, Treatment, and Technician Characteristics

Over a 7-month period, we identified 117 patients who received a total of 749 measured treatments. The mean age was 55 years, about half were black, and about half were male (*Table I*). The mean blood flow rate was 378 ml/min, and the mean treatment duration was 220 minutes.

Twenty-seven technicians provided care during these treatments. The mean number of measured treatments per technician was 28.

Probable Measurement Errors

Using the criterion of a delivered Kt/V that was 25% greater than the prescribed Kt/V, 24 (3%) of 749 total treatments had probable measurement errors. On univariate analysis, several patient and treatment characteristics were associated with a higher error rate. The error rate was 7% for patients with end-stage renal disease due to a cause other than diabetes or hypertension (*Table II*). The error rate was 8% for treatments with a blood flow rate < 360 ml/min, and 5% for treatments with a duration of < 3.5 hours (*Table III*). There was no relationship between error rate and the number of treatments provided by each technician (*Table IV*). On multivariate analysis, only low blood flow rate was independently associated with the occurrence of probable measurement errors.

Table II. Univariate relationship between patient characteristics (n = 117) and probable treatment errors.

	n	% errors
Age (yr)		
< 50	43	3.4
50–65	39	1.8
> 65	35	4.9
Race		
black	62	2.9
white	54	3.7
other	1	0
Gender		
male	62	3.5
female	55	3.0
Cause of renal failure*		
hypertension	47	3.8
diabetes	46	0.9
other	24	6.7
Mean patient volume (L)		
< 38	39	2.2
38–45	40	2.8
> 45	38	4.8

*$p = 0.01$

Measurement Errors by Individual Technicians

The 27 technicians varied greatly in their error rate, with a range from 0% to 28% (*Figure 1*). Four technicians, with error rates of 12–28%, were significantly different from other technicians even after adjusting for other factors that were found to be significant on univariate analyses (i.e., patient's cause of end-stage renal disease, blood flow rate, and treatment duration). In separate stepwise multivariate analyses, measurement error was independently associated with receiving treatment from these specific technicians (odds ratio 5.5, $p < 0.001$), and with blood flow rate < 360 ml/min (odds ratio 13.8, $p < 0.001$).

Other Definitions of Probable Measurement Errors

Twelve percent of treatments had a delivered Kt/V that exceeded the prescribed Kt/V by 10% or more, and 2% exceeded the prescribed Kt/V by 33% or more. However, the same four technicians were identified as outliers regardless of the definition of probable measurement error (results not shown).

Discussion

Errors in post-dialysis blood sampling may result from inappropriate timing of blood draw, blood or dialysate flow rates that are too fast, dialysis access recirculation, and mixing of patient blood with heparin or saline.[9,10] These factors falsely lower post-dialysis blood urea nitrogen and result in an overestimation of the delivered dialysis dose. Thus, treatments in which delivered Kt/V appears to substantially exceed prescribed Kt/V probably result from errors in post-dialysis blood sampling. Using this rationale, we found that probable measurement errors occur in an appreciable proportion of treatments. More importantly, much of the variation in error rate was related to specific personnel.

Identifying a clustering of errors within certain providers is an important first step in quality improvement efforts. We recommend that facilities monitor probable measurement errors for all technicians and provide directed education to those with high error rates. This is more likely to be successful if part of a collaborative quality improvement effort as opposed to a punitive approach.[11] Note that improving the accuracy of post-dialysis blood sampling will slightly decrease the Kt/V performance of the facility, since the number of falsely elevated Kt/Vs will be reduced.

Our findings are consistent with previous studies that documented wide variation in blood sampling techniques across facilities. In one study, 15% of facilities drew samples without decreasing blood flow, 47% drew samples immediately after slowing blood flow, 9% maintained a 20- to 60-second period of slow flow, and 28% maintained a 1- to 15-minute period of slow flow.[5] In another study, variations in sampling were noted in 8–42% of facilities, depending on the definition of appropriate sampling technique.[6] However, neither of these studies examined variation across technicians. Examining individual practices as well as the relation of these practices to established protocols is an important step in quality improvement processes.[12]

It is unclear why low blood flow rate is associated with increased error rate. Low blood flow rate may be a marker for a poorly functioning vascular access. Recirculation in a poorly functioning access may result in a falsely low post-dialysis blood urea nitrogen.[10,13] However, we did not find an association between catheter use (which is often accompanied by recirculation[14]) and error rate. The finding of an error rate that was higher in patients with diagnoses other than diabetes or hypertension is likewise unclear. It should be noted that in multivariate analyses this association was not found.[15]

Several limitations must be considered in interpreting our results. First, we focused on a modest sample of patients and technicians from a single facility. Second, our patients were more likely to be black or to have hypertension as a cause of renal failure compared to patients nationally.[16] This likely reflects the urban location of the dialysis facility. Third, we did not have data on technician characteristics such as years of dialysis experience, type of training in sampling techniques, or the exact method that each technician used to sample blood. Fourth, our prescribed Kt/V calculation is likely to be an overestimate, since we relied on manufacturers' specifications for dialyzer performance. These specifications, based on in-vitro performance, tend to overestimate the in-vivo performance by 10–20%.[17] Thus, making this adjustment would further increase the proportion of treatments labeled as probable measurement errors. Fifth, we did not collect data regarding dialyzer reuse or total cell volume. Since reuse can slightly decrease

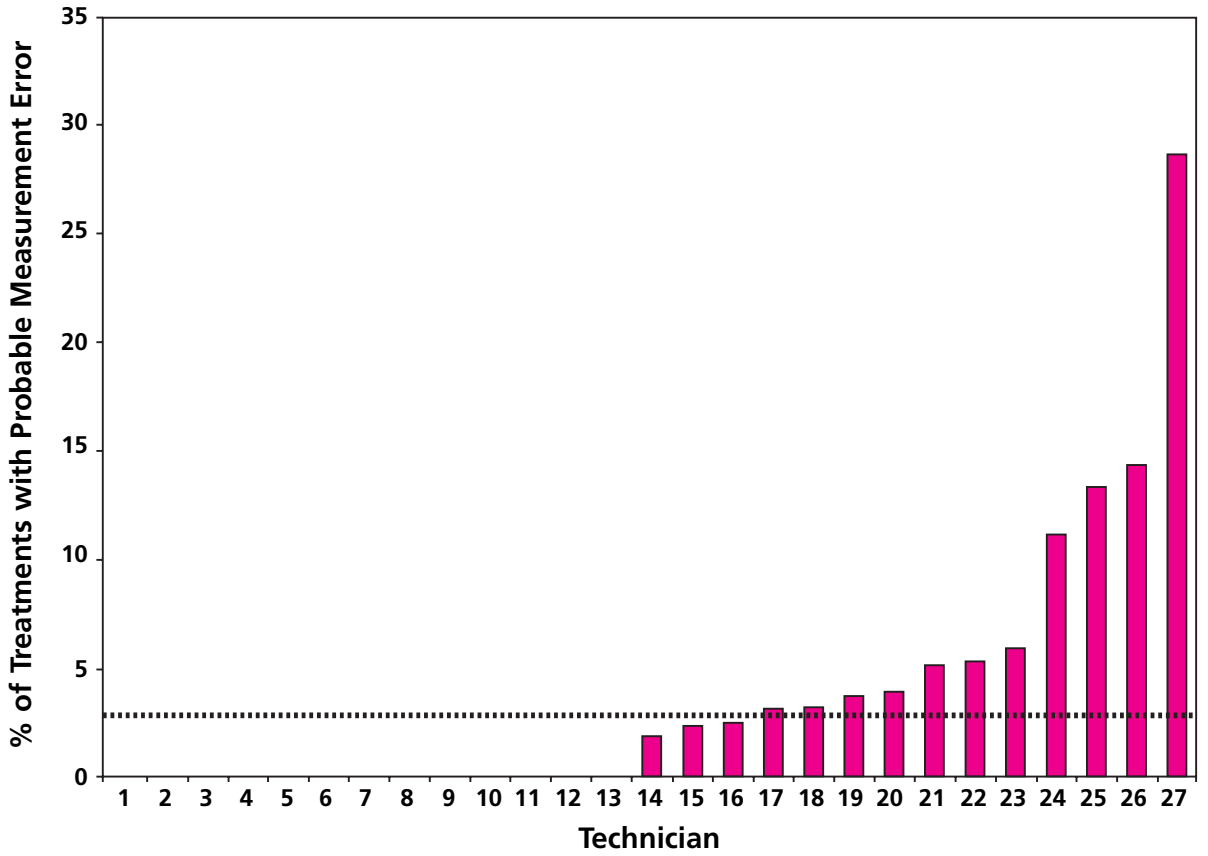

Figure 1. Percent of treatments with probable measurement error among each of 27 technicians. Dotted horizontal line indicates the group mean treatment error rate of 3%.

dialyzer efficiency, failing to account for reuse may also have resulted in an overestimate of prescribed Kt/V.[18]

Conclusion

In conclusion, probable errors in post-dialysis blood sampling occur in an appreciable proportion of treatments. Moreover, much of the variation in error rate is related to specific personnel. Efforts to monitor and educate facility personnel on practice guideline-based blood sampling methods may improve the accuracy of hemodialysis dose calculations.

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Table III. Univariate relationship between treatment characteristics (n = 749) and probable treatment errors.

	n	% errors
Dialyzer		
F80	647	3.3
CT190	71	3.2
F70	31	2.8
Dialysis access type		
graft	419	3.1
fistula	193	3.1
catheter	137	3.7
Blood flow (ml/min)*		
< 360	250	8.4
360–405	236	0.4
> 405	263	0.8
Treatment duration (min)†		
< 210	277	5.0
210–240	223	2.0
> 240	249	2.0

*$p < 0.01$; †$p < 0.05$

Table IV. Univariate relationship* between technician characteristics (n = 27) and probable treatment errors.

	n	% errors
Total treatments provided		
< 140	9	4.8
140–520	9	3.7
> 520	9	3.1
Measured treatments provided		
< 8	9	4.8
8–35	9	4.4
> 35	9	2.4

*p = NS

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