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Use of Relative Blood Volume Monitoring to Reduce Intradialytic Hypotension in Hospitalized Patients Receiving Dialysis

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INTRODUCTION

Intradialytic hypotension (IDH) is a frequent complication of hemodialysis in hospitalized patients with acute kidney injury (AKI) who require renal replacement therapy and those with end stage kidney disease (ESKD), occurring between 20% and 30% of the time.[1,2] IDH results in significant morbidity and mortality, often results in shorter dialysis treatment times and consequently resulting in less adequate dialysis doses.[3]

Relative blood volume monitoring (RBVM) is used to monitor hematocrit and oxygen saturation and continuously reports the change in intravascular blood volume during dialysis.[4] These data are monitored in real time and the dialysis treatment can be modified accordingly. Most of the RBVM data has been collected in the outpatient setting during chronic dialysis sessions.[5,6,S1] These studies have employed RBVM predominantly with goals to improve blood pressure control and ensure adequate volume removal but data are conflicting. Some studies have shown that RBVM improves blood pressure and decreases hospitalizations,[5,6] whereas others have shown no improvement in IDH and potential worsening of hospitalizations among patients with ESKD.[7] Data on the use of RBVM in the acute hospital setting is scarce.

We performed a prospective quality improvement study to examine the hypothesis that using RBVM during acute hemodialysis sessions for hospitalized patients with AKI requiring renal replacement therapy and those with ESKD would reduce IDH.

RESULTS

A total of 328 patients were included in this study, 161 during the control period and 167 during the intervention period. Patient characteristics were similar during both time periods (Table 1). We examined data from 357 acute dialysis treatments during the control period and 321 acute dialysis treatments during the intervention period. IDH occurred during 23.5% of all dialysis treatments during the control period and 18.7% during the intervention period, but the difference was not significant, odds ratio 0.75 (0.47–1.1), $P = 0.22$ (Table 2). There were no significant differences in modifications made to the dialysis treatments or patient symptoms (Table 2). There was no difference in ultrafiltration rate between the control and intervention period (6.5 ± 3.6 vs. 7.0 ± 3.5 ml/kg/h, respectively, $P = 0.08$). Length of hospital stay was significantly longer during the RBVM period compared to control (20.8 ± 29.7 days vs. 15.0 ± 22.2 days, respectively, $P = 0.04$). There was no significant difference in length of stay in the intensive care unit (ICU) between the RBVM and control periods (15.3 ± 23.0 days vs. 10.0 ± 13.8 days, respectively, $P = 0.09$). Of the patients with AKI ($n = 94$), there was no difference in IDH events between the control and RBVM periods (IDH occurred in 25.9% vs. 24.3%, respectively, $P = 0.85$).

Seventy-two patients received portable dialysis treatments in the ICU. Baseline demographics for ICU patients are shown in Table 1. When examining portable dialysis treatments delivered to patients in the ICU, there was a 29% reduced odds of IDH when using RBVM compared to the control period (odds ratio 0.71, 95% confidence

Table 1. Baseline demographics of participants

Baseline characteristics	Control period	RBVM period
All Participants (count)	($n = 161$)	($n = 167$)
Age (yrs)	56.9±15.0	56.2±15.0
Female *N* (%)	66 (41.0)	68 (41.0)
Race/Ethnicity *N* (%)		
White	82 (50.9)	86 (51.5)
Black	38 (23.6)	42 (25.2)
Hispanic/Latino	45 (28.0)	47 (28.0)
ESKD *N* (%)	114 (70.8)	120 (71.9)
AKI *N* (%)	47 (29.2)	47 (28.1)
Diabetes *N* (%)	84 (52.2)	81 (48.5)
HTN *N* (%)	142 (88.2)	139 (83.2)
CVD *N* (%)	55 (34.2)	63 (37.8)
Obstructive sleep apnea *N* (%)	37 (22.9)	43 (25.7)
Sepsis *N* (%)	35 (22.0)	47 (28.0)
Circulatory shock *N* (%)	22 (13.7)	23 (13.8)
Admission to ICU *N* (%)	33 (20.5)	39 (23.4)
ICU patients receiving portable dialysis (count)	($n = 33$)	($n = 39$)
Age (yrs)	60.8±13.2	56.0±16.8
Female *N* (%)	14 (42.4)	14 (38.5)
Race/Ethnicity *N* (%)		
White	20 (60.6)	19 (48.7)
Black	8 (24.2)	11 (28.2)
Hispanic/Latino	5 (15.2)	9 (23.1)
ESKD *N* (%)	14 (42.4)	23 (59.0)
AKI *N* (%)	18 (54.5)	16 (41.0)
Diabetes *N* (%)	13 (39.4)	17 (43.6)
HTN *N* (%)	26 (78.8)	32 (82.1)
CVD *N* (%)	13 (39.4)	16 (41.0)
Obstructive sleep apnea *N* (%)	8 (24.2)	10 (25.6)
Sepsis *N* (%)	15 (45.5)	16 (41.0)

AKI, acute kidney injury; CVD, cardiovascular disease; ESKD, end stage kidney disease; HTN, hypertension; RBVM, relative blood volume monitoring; ICU, intensive care unit
All values are mean±SD.

interval 0.51–0.99, $P = 0.04$, Table 2). Similar to the overall group, there were no significant differences in modifications to the dialysis treatments or patient symptoms during treatment with RBVM (Table 2). There was no difference in ultrafiltration rate (6.2 ± 3.3 vs. 7.3 ± 4.2, respectively $P = 0.22$) or length of stay (28.5 ± 29.4 days vs. 28.3 ± 40.0 days, respectively, $P = 0.21$).

DISCUSSION

We found that the use of RBVM was associated with a 29% reduction in IDH in patients undergoing dialysis in the ICU. These finding suggest that RBVM may be useful to reduce IDH in critically ill patients. We did not find any significant difference in IDH with RBVM in all patients undergoing hemodialysis in the hospital. This may indicate that if patients are stable enough to be dialyzed in the acute dialysis unit and not at bedside then RBVM may not be as helpful at reducing IDH.

The majority of data regarding RBVM in dialysis comes from outpatient patients with ESKD and is conflicting.[5–7] Fewer studies have been performed in the inpatient setting. Critically ill patients are already prone to having hemodynamic instability and multi-organ dysfunction, and thus are at greater risk than general inpatients for developing hypotension and ischemic complications. Even a 5% reduction in IDH may be clinically meaningful. Nevertheless, data regarding reductions in IDH and actual clinical outcomes in hospitalized patients are lacking.

In a small study of 21 critically ill patients with sepsis and AKI, RBVM was found to be an easy and feasible tool to guide fluid management because investigators were able to maintain balance between ultrafiltration and vascular refilling.[8] A small study of 20 adult patients with AKI found that the use of RBVM resulted in decreased IDH rates.[S3] Nevertheless, in a study of 74 critically ill patients with AKI, the use of RBVM did not reduce IDH in the ICU setting.[S4] This study had a significantly lower rate of IDH (only 17%) compared to other studies. In our study, we did not find any significant reduction in IDH when examining only patients with AKI requiring renal replacement therapy. In our ICU patients, a large percentage had ESKD. Therefore, the use of RBVM to reduce IDH may differ in patients

Table 2. Differences in outcomes between control and relative blood volume monitoring periods

	Control period	RBVM period		
	Number of events (%)	Number of events (%)	Odds ratio (95% CI)[a]	*P* value
All patients	($n = 357$ treatments)	($n = 321$ treatments)		
Intradialytic hypotension	84 (23.5)	60 (18.7)	0.75 (0.47–1.11)	0.22
Frequency of saline/albumin given	84 (23.5)	60 (18.7)	0.75 (0.50–1.11)	0.16
Change in blood flow rate	71 (20.5)	80 (25.2)	1.3 (0.87–1.96)	0.20
Shortened treatment time	27 (7.6)	25 (7.8)	1.03 (0.59–1.81)	0.91
Adverse patient symptoms during treatment	43 (12.0)	38 (11.8)	0.98 (0.61–1.59)	0.94
ICU patients	($n = 52$ treatments)	($n = 46$ treatments)		
Intradialytic hypotension	2 (46.2)	11 (23.9)	0.71 (0.51–0.99)	0.04
Frequency of saline/albumin given	21 (40.4)	12 (26.1)	0.52 (0.21–1.28)	0.16
Change in blood flow rate	20 (39.2)	17 (37.0)	0.91 (0.40–2.06)	0.82
Shortened treatment time	5 (9.6)	4 (8.7)	0.89 (0.25–2.75)	0.85
Adverse patient symptoms during treatment	7 (13.5)	5 (10.9)	0.78 (0.22–2.75)	0.70

CI, confidence interval; ICU, intensive care unit; RBVM, relative blood volume monitoring.
[a]Odds ratio (95% CI) of outcome RBVM compared to control.

with AKI versus ESKD and large prospective randomized studies are needed.

Length of stay in the hospital was significantly longer in the intervention period. The reason for this is not clear but needs to be explored in future studies examining the use of RBVM in the hospital setting. Of note, length of stay in the ICU was not different between the 2 periods.

Our study does have limitations. First, this was not a randomized controlled trial. In addition, we could not detect differences in the outcomes because this was a quality improvement study. The number of patients undergoing dialysis in the ICU was small and may have limited power to detect significant differences. We defined AKI by chart review of nephrology notes, not by increases in serum creatinine levels. Finally, nursing competency in using RBVM was determined by supervisors and not by written knowledge testing. Strengths of this study include a large patient population for a quality improvement initiative, use of a run-in period to ensure nurses were capable and comfortable using RBVM and utilization of existing technology already on the dialysis machines with no significant change in or addition to the normal workflow of dialysis nurses and/or physicians.

In conclusion, the use of RBVM reduced IDH in critically ill patients undergoing intermittent hemodialysis in the ICU. These results suggest the need for a large, randomized controlled trial looking at use of RBVM in ICU patients undergoing dialysis and clinical outcomes.

DISCLOSURE

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AUTHOR CONTRIBUTIONS

MM, AB, JK contributed to the study conception and design. All authors contributed to data acquisition and interpretation. All authors contributed to the drafting, revising and final approval of the version to be published. All authors are in agreement to be accountable for all aspects of the work prepublication and postpublication.

SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Supplementray Methods.

Supplementary References.

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