Lung Ultrasonographic Assessment of Volume Status in Hemodialysis Patients

Justin Dragoman BSc [1], Chi Zhang MD, FRCPC [2,3], Marlene Johnson BScN, RN, cNEPH [2], DharmaPaul L. Raju MD, FRCPC, FASN [2,3]

[1] Faculty of Medicine, University of British Columbia, [2] Department of Nephrology, KBRH, [3] Division of Nephrology, University of British Columbia

Background

Assessment of volume status is a critical component of the clinical management of hemodialysis (HD) patients. Volume overload is one of the most common causes of hypertension in HD patients and an independent risk factor for death from cardiovascular disease. Subjective clinical examination is currently the standard of care in volume assessment despite its significant limitations.

Adjusting the **dry weight (DW)** to reduce volume overload and control hypertension without precipitating **intradialytic hypotension (IDH)** is a therapeutic aim of HD. IDH is defined as a decrease in systolic blood pressure by ⩾20 mm Hg or a decrease in mean arterial pressure by ⩾10 mm Hg, and is associated with symptoms such as cramping, nausea, vomiting and abdominal pain. Reoccurring symptoms make patients less adherent to attending dialysis sessions. Moreover, IDH causes relative demand ischemia, CHF, cerebral hypoperfusion and increased all cause mortality. DW is defined as the lowest post HD weight achievable without causing signs or symptoms of hypotension.

Lung ultrasonography (LUS) relies on the presence of B-lines to represent extravascular lung water (EVLW). B-lines are defined as hyperechoic lines originating at the pleura and spreading to the edge of the screen. B-lines move with respiration and eliminate transverse A-lines. LUS has shown to be a much better predictor of extravascular lung water than simple auscultation of the lung fields. The effects of LUS guided weight targeting has been shown to improve ambulatory blood pressure control without increasing IDH.

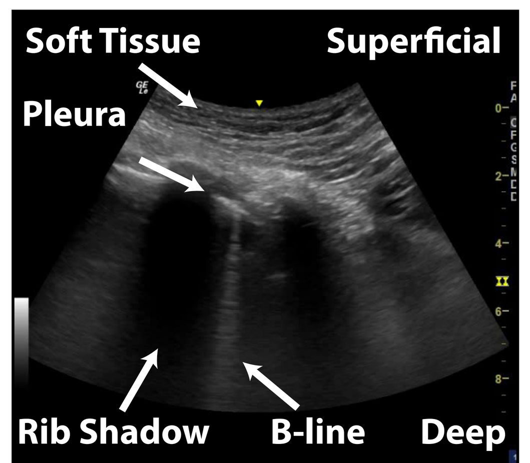

Figure 1. Example B-line

The aim of this project was to utilize point of care ultrasound (POCUS) to find pulmonary congestion in HD patients and safely **ultrafiltrate (UF)** patients without precipitating IDH. Additionally, we wanted to use POCUS to identify patients with subclinical CHF who would likely benefit from additional UF thereby preventing hospitalizations for acute decompensated CHF. Finally, we seek to determine if there is a correlation between brain natriuretic peptide (BNP) and the number of B-lines seen on LUS.

Methods

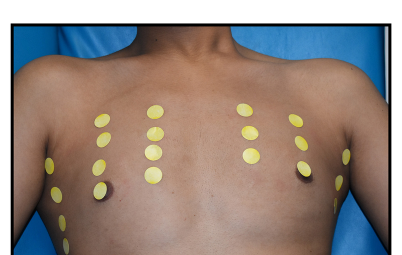

Figure 2. Scan location

11 HD patients with a history of IDH were recruited into the project after informed consent. Patients received LUS before dialysis in the parasternal, mid-clavicular, anterior axillary, and mid-axillary lines from the 2nd - 5th rib interspace (2nd - 4th on the left). B-lines were totalled and same-day BNPs were drawn if appropriate. The intervention start was marked by the first scan.

A baseline period of 2 weeks prior to the intervention assessed dry weight, probability and duration of IDH, systolic blood pressure (sBP), and patient characteristics. LUS was incorporated into the physical exam and decisions to challenge dry weight.

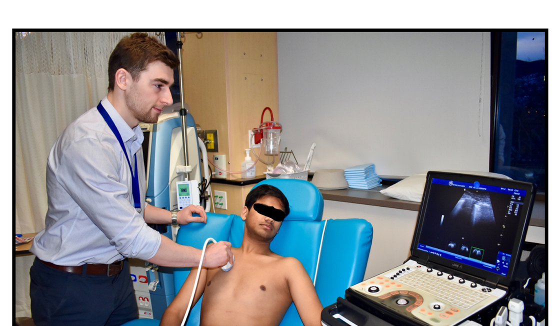

Figure 3. An example scan

Data was analysed in Matlab where mean, standard deviation, statistical significance (using a two-sided t-test), and correlation coefficients could be calculated (Figure 4). A p-value of ⩽0.05 was deemed significant. Box plots were used to display non-gaussian data.

Results

Values are reported as mean ± standard deviation for gaussian distributed variables and median (interquartile range) for non-gaussian variables. Fraction of time normotensive was computed for each dialysis session and then averaged for a single patient. The 11 patients were then averaged and error on the mean was computed as $\sigma_{avg} / \sqrt{(N-1)}$, where σ_{avg} is the standard deviation of the patient averages and N is the number of patients.

11 patients were followed during 263 dialysis sessions. Patient characteristics can be found in Table 1. Patients were followed for a median 7 (3) sessions retrospecively and a median 14 (15) sessions prospectively.

CHARACTERISTIC	
NUMBER OF PATIENTS	11
AGE (YEARS)	67 ± 15
MALE, N (%)	8 (72)
HEIGHT (CM)	172 ± 16
BMI (KG/M²)	35 ± 9
DIALYSIS VINTAGE, MO (MEDIAN, IQR)	18 (50)
HYPERTENSION, N (%)	10 (91)
RAAS BLOCKER, N (%)	6 (54)
BB / CCB, N (%)	10 (91)

Table 1. Main demographic and anthropometric data for participants in the project.

Dry weight was computed in two ways using the post-dialysis weight. The first averaged each patient's pre- and post-intervention dry weights and averaged values across all patients. Error on the mean was computed as above. The second method averaged dry weights for 1 week before each lung ultrasound and 1 week after lung ultrasound. This method allowed a focussed look at the intervention effects.

Table 2. Summary of the results for participants in the project.

RESULT	PRE-INTERVENTION (MEAN ± SD)	POST-INTERVENTION (MEAN ± SD)	P-VALUE
FOLLOW UP (DAYS)	14 ± 21	46 ± 21	-
PERCENTAGE OF TIME NORMOTENSIVE (%)	63 ± 8%.	75 ± 5%	0.03
PROBABILITY OF HYPOTENSION (%)	78 ± 7%	53 ± 6%	0.02
B-LINES (#)	20 ± 7	14 ± 3	0.02
WEIGHT (KG)	100 ± 9	100 ± 9	0.9
PERIDIALYSIS WEIGHT (KG)	102 ± 10	101 ± 10	1.0

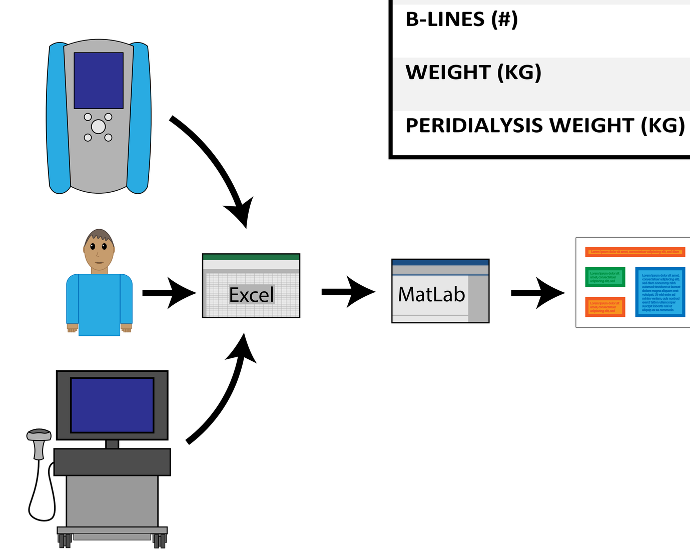

Figure 4. Workflow for the Ultrasound project. Patient data, ultrasound results and dialysis parameters were collected in an Excel file and analysed in MatLab.

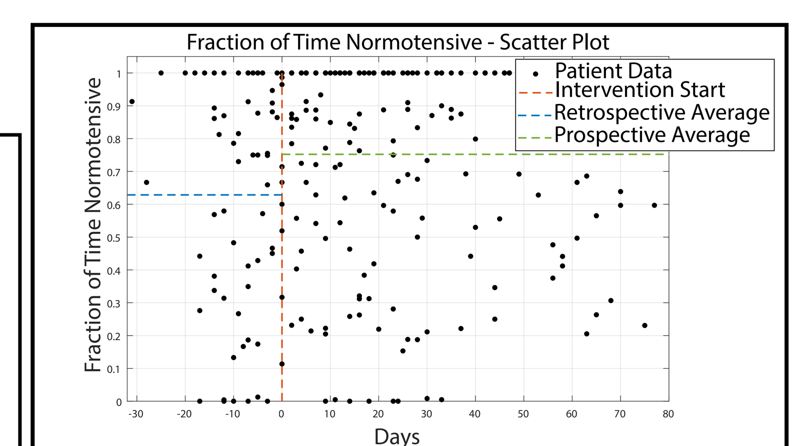

Figure 5. Scatter plot of fraction of time normotensive. Pre-intervention values were separated from post-intervention values. The mean was calculated and compared before and after intervention. A fraction of 1 represents no occurence of hypotension during dialysis. Any value less than 1 represents some period of hypotension.

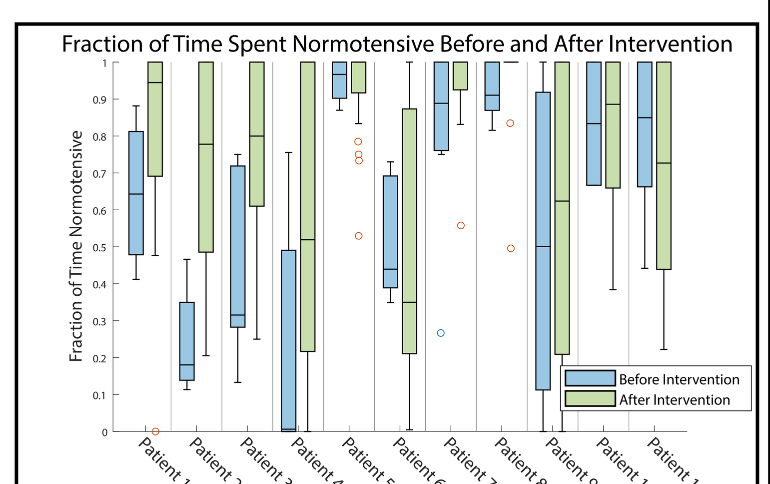

Figure 6. Box plot comparing the fraction of time spent in normotension during the pre- and post-intervention period. Outliers are marked in circles.

Results Cont.

BNP values drawn within 48 hours of LUS were compared to investigate correlation. 25 measurements were compared. A correlation coefficient of -0.1 ± 0.2 (p = 0.5) was computed.

There was a decrease in the average number of B-lines during the pre- and post-intervention period (p = 0.02).

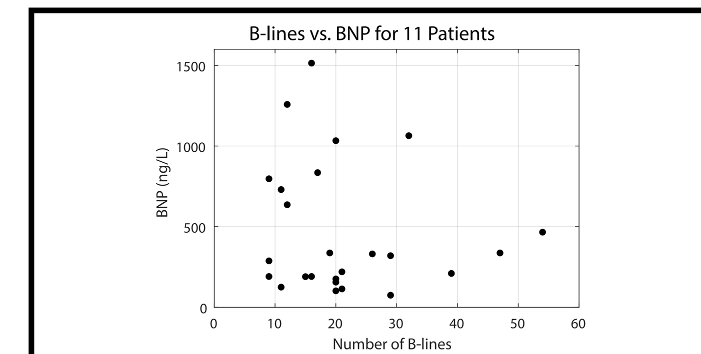

Figure 8. BNPs within 48-hours of B-line measurement. No statistical correlation observed (Table 2).

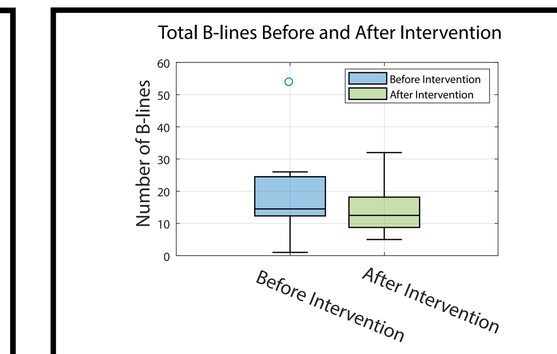

Figure 7. Number of B-lines in the pre- and post-intervention periods.

Discussion

We implemented a new program at KBRH to explore the hypothesis that utilizing Point of Care Ultrasound (POCUS) is useful to identify extravascular lung water as a marker of volume overload.

Our project demonstrated that there was a statistically significant reduction in the duration and probability of IDH among our HD patients. We also demonstrated a statistically significant decrease in B-lines after increased ultrafiltration. Most patients were asymptomatic, indicating that we identified patients with subclinical volume overload which was improved after targeted UF. There was no observed difference in dry weight before and after intervention, which we attributed to the limited follow-up period. However, each patient's dry weight changed throughout the intervention, possibly reaching the optimal value.

There was no statistical correlation between serum BNP levels and US-B lines. Further analysis of this relationship is required. The cost associated with ordering BNP levels in our HD population last year was almost $6,000.00 (for reagent alone) indicating an area to mitigate costs.

This project has shown that we are able to reduce the number of US-B lines and duration of IDH using ultrasound-guided dry weight adjustments. A second cohort of study participants will start in the fall of 2020.

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