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Impact of Alarm Frequency on Dialysis Adequacy using Online Clearance Monitor System in Haemodialysis Machine: A Cross-sectional Study

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ABSTRACT

Introduction: Haemodialysis (HD) adequacy is critical for patient outcomes. Alarms frequently interrupt treatments, making it important to understand the relationship between alarm frequency and dialysis adequacy (Kt/V).

Aim: To evaluate the impact of HD machine alarm frequency on dialysis adequacy using the Online Clearance Monitor (OCM).

Materials and Methods: This cross-sectional study was conducted at the Dialysis Unit of Yenepoya Medical College Hospital, Mangaluru, Karnataka, India, from September 2023 to May 2024, involving 43 HD patients. OCM was used to determine HD adequacy. Data such as postdialysis weight, haemoglobin, Kt/V goal achievement and alarm occurrences during the four-hour session on Fresenius 4008S machines were collected. Regression analysis was employed to examine the association between adequacy and alarm frequency.

Results: The study population comprised 12 females and 31 males, with a mean age of 51.44±15.822 years. The mean frequency of alarm muting was 2.02±2.858 times per treatment, with an average achieved Kt/V of 1.251±0.088. Conductivity alarms were the most frequent (mean±SD=4.55±3.83), followed by upper and lower vein alarms. Multiple linear regression analysis revealed a statistically significant positive association between alarm muting frequency and Kt/V values {β=0.010, 95% CI (0.0011, 0.0195), p-value=0.0282}.

Conclusion: The study found that increased alarm muting frequency was associated with improved dialysis adequacy, as measured by Kt/V. This suggests that selective alarm muting based on clinical judgment may not negatively impact treatment effectiveness. However, further research is needed to establish optimal protocols for alarm management that balance treatment efficiency with patient safety.

Keywords: Clinical alarms, Kidney failure, Renal dialysis

INTRODUCTION

HD is a medical treatment used to remove excess metabolic waste and fluid from the blood of patients with Chronic Kidney Disease (CKD) or End-Stage Renal Disease (ESRD). HD machines are designed to perform this treatment. However, various factors influence the efficiency and effectiveness of HD treatments and one such factor is the frequency of alarms in HD machines. These alarms are warning signals that the HD machine generates to alert healthcare providers about potential issues or problems during the treatment, such as low blood flow rates or interruptions in the dialysis process [1].

The frequency of alarms in HD machines can significantly impact the adequacy of HD treatments, as frequent alarms can disrupt the treatment flow and result in suboptimal clearance of waste and excess fluid from the blood [2]. The assessment of dialysis dose is crucial since extensive evidence shows that patient survival depends on treatment adequacy [3]. The adequacy of HD treatments can be impacted by various factors, such as session-to-session variation in individual patients, which has been shown to influence treatment quality. This makes monitoring dialysis doses in each session critical. Studies have found that HD treatment quality is often suboptimal, with 15-20% of patients receiving inadequate dialysis doses [3].

To address this issue, the use of OCM has been proposed as a method of continuously monitoring the clearance of waste and excess fluid from the blood during HD treatments. This information can be used to evaluate the impact of alarm frequency on the adequacy of HD treatments and make necessary adjustments to improve the efficiency and effectiveness of treatments [4].

OCM functions by measuring ionic dialysate, which is closely related to urea clearance [5]. This involves using a second conductivity cell in the effluent dialysate. OCM offers a safe and accurate method for real-time monitoring of total urea clearance [5,6]. Different methods of online urea concentration and clearance monitoring have been suggested for controlling dialysis dose (Kt/V) and Protein Catabolic Rate (PCR) [6]. Some systems, such as the DQM 200, are separate modules that provide results such as Total Removed Urea (TRU), Urea Reduction Ratio (URR), Kt/V, equilibrated Kt/V, PCR, and normalised PCR [6]. The UM 1000 presents results as cumulative urea removal, Kt/V during dialysis, Kt/V at the session's end, and PCR at the session's end [6].

Fresenius Medical Care (FMC) HD machines offer Effective Ionic Dialysance (EID) [6]. The Fresenius 4008S machine, equipped with OCM, facilitates conductivity monitoring to measure EID, an online measure of effective urea clearance calculated using changes in dialysate sodium conductivity [5,7]. EID provides a reliable, real-time, non invasive and inexpensive measurement of dialysis dose during an HD session [5,8]. Alarm Management Systems (AMS) in HD are crucial for patient safety, monitoring various parameters and alerting staff to potential issues. However, frequent alarms can disrupt HD treatment and lead to inadequate dialysis. AMS uses two different notification models: local or on-floor monitoring and remote monitoring. The former is primarily located within the care unit and notifies the nursing staff directly, while the latter manages all alarms from a distance using technical staff members who monitor alarms from multiple care units [9].

There is a need to assess the impact of alarm frequency on HD adequacy and to determine whether decreased alarm frequency in HD machines results in improved clearance of metabolic waste and excess fluid from the blood during HD treatment. The findings from this study can contribute to improvements in the design and implementation of HD machines, ultimately enhancing treatment efficiency and effectiveness. The primary objective of this study was to evaluate the impact of HD machine alarm frequency on HD treatment adequacy through continuous OCM.

MATERIALS AND METHODS

This cross-sectional study was conducted in the Dialysis Unit of Yenepoya Medical College Hospital, Mangaluru, Karnataka, India, from September 2023 to May 2024. The study was approved by the Institutional Ethics Committee at Yenepoya Medical College Hospital (YEC2/2023/080). Written informed consent was obtained from all enrolled patients.

Inclusion criteria: People receiving HD on the Fresenius 4008S HD machine and who were undergoing maintenance HD for at least four hours in a single dialysis session were included in this study.

Exclusion criteria: Outpatient maintenance HD patients with hepatitis B and hepatitis C, as well as patients undergoing dialysis in the inpatient ward or in the intensive care unit, were excluded from the study.

Sample size calculation: Considering the anticipated prevalence of HD adequacy as 50%. The sample size was calculated as:

$$n=\frac{z^2p(1-p)}{E^2}$$

where, Z=1.96, the standard normal score, p=50%, E=15%, the margin of error. The sample size required was 43.

OCM was utilised to assess HD adequacy. Data were collected during routine HD sessions. The following parameters were collected from the dialysis machine and patient records: postdialysis weight, haematocrit value, Kt/V goal achieved and alarms occurring on the Fresenius 4008S machine during the four-hour session. Kt/V was used to quantify HD adequacy [10]. Here, K represents the urea clearance, t is the duration of dialysis, and V signifies the volume of distribution of urea [10].

The OCM was set to run for the entire four-hour dialysis session. Prior to the session, postweight and haematocrit values were determined and entered into the OCM. The Kt/V target was set to 1.4 for patients attending twice-weekly sessions and 1.2 for those attending three times a week. The Fresenius 4008S machine was monitored for OCM settings, and the achievement of the Kt/V goal was recorded. The number of alarms triggered and muted by the alarm system was also recorded.

STATISTICAL ANALYSIS

Statistical analysis was performed using R Studio version 4.1.2. Regression analysis was employed to assess the impact of alarm frequency on HD treatment efficiency, as measured by OCM data. Statistical significance was considered at p-value <0.05.

RESULTS

A total of 43 HD patients were enrolled in the study. The mean age of participants was 51.44±15.822 years. The sample comprised 12 females (27.9%) and 31 males (72.1%). All patients were treated using Fresenius 4008S HD machines and the average time spent on dialysis was four hours. The mean frequency of alarm muting was 2.02±2.858 times per treatment session. The average Kt/V value achieved was 1.251±0.088, with a mean goal achievement score of 1.27±0.637 [Table/Fig-1].

The conductivity alarm was found to be the most frequent (n=11, mean±SD=4.55±3.83), followed by upper and lower vein alarms (n=10 each). Less frequent alarms included lower Transmembrane Pressure (TMP) alarms (n=5, 3.8±3.27) and air detector alarms (n=2, 2.5±0.71) [Table/Fig-2].

Variables	Mean±SD
Age	51.44±15.822
No. of times muted	2.02±2.858
Kt/V	1.251±0.088
Goal achieved	1.27±0.637

[Table/Fig-1]: Descriptive statistics of study variables.

Type of alarm	Number of participants	Mean±SD	Minimum	Maximum
Conductivity alarm	11	4.55±3.83	1	11
Upper vein alarm	10	2.6±1.43	1	6
Lower vein alarm	10	3.7±1.89	1	6
Air detector	2	2.5±0.71	1	3
Lower TMP alarm	5	3.8±3.27	1	9
Upper TMP alarm	1	8±-	-	-
Blood leak alarm	2	1±0	1	1
BLD dismiss alarm	1	1±-	-	-
Relation between BF/UFR	1	1±-	-	-

[Table/Fig-2]: Distribution of types of alarms during treatment.
TMP: Transmembrane pressure; BLD: Blood leak detector, BF: Blood flow; UFR: Ultrafiltration rate

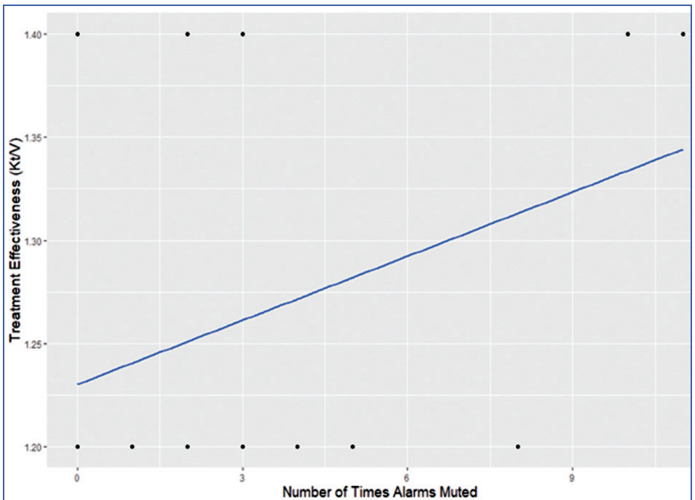
The analysis revealed a significant positive association between the number of times alarms were muted and Kt/V values {β=0.010, 95% CI (0.0011, 0.0195), p-value=0.0282} [Table/Fig-3].

Predictors	Beta	Confidence interval		p-value
		Lower bound	Upper bound	
Constant	1.23	1.198	1.262	<0.001
No. of times alarm muted	0.010	0.0011	0.0195	0.0282*

[Table/Fig-3]: Multiple linear regression analysis for predictors of dialysis treatment effectiveness.

The regression equation can be expressed as Z (Kt/V)=1.23+0.010 × (No. of times muted). This equation helps to understand how the effectiveness of dialysis treatments (Kt/V) is related to the number of times the machine alarms are muted. The equation indicates that the baseline effectiveness (Kt/V) is 1.23 when no alarms are muted, with an increase of 0.010 units in Kt/V for each additional alarm muting event. For example, ten instances of alarm muting would correspond to a predicted Kt/V increase from 1.23 to 1.33. In simple terms, more frequent muting of the alarms leads to a small improvement in the dialysis treatment's effectiveness.

The relationship between the alarm muting frequency and treatment effectiveness is illustrated in the scatter plot [Table/Fig-4]. The plot



[Table/Fig-4]: Scatter plot with alarm muting frequency on x-axis and Kt/V values on y-axis, including the regression line.

demonstrates a positive linear trend, supporting the regression analysis findings that increased alarm muting frequency is associated with improved treatment effectiveness as measured by Kt/V values.

DISCUSSION

This study examined the relationship between the frequency of alarms during HD and the adequacy of dialysis treatment, measured by Kt/V. The findings showed a statistically significant positive association between the number of times alarms are muted and Kt/V (p-value=0.0282). This suggests that the dialysis staff may selectively mute alarms based on clinical judgment, prioritising uninterrupted treatment while ensuring safety. This practice occurs within the context of ensuring dialysis adequacy, which is a critical factor influencing patient survival and treatment quality [3].

The demographic composition of this study population showed a predominance of male participants (72.1%) with a mean age of 51.44±15.822 years. This differs somewhat from the population studied by Mansur A et al., who reported a mean age of 56.46±13.82 years in their study of HD adequacy [11]. The study by Zhang L et al., involved a population with a mean age of 51.5±12.2 years, with 86.7% males, further emphasising the variability in patient demographics across different studies [3].

The integration of OCM presents a promising avenue for improving dialysis adequacy monitoring. As demonstrated by Daugirdas JT and Tattersall JE, machine-based monitoring methods can provide several advantages, such as the ability to detect access recirculation immediately, monitor dialyser performance in real time and ensure the delivery of prescribed dialysis doses in each session [12].

The mean Kt/V in present study was 1.251±0.088, meeting the minimum KDOQI recommendation of 1.2 but falling below the optimal 1.4 threshold [13]. Alarm frequency analysis revealed that conductivity alarms were the most common; the probable reason could be due to the inappropriate mixing and depletion of dialysis fluid, followed by lower vein pressure alarms and upper vein pressure alarms. Conductivity-based monitoring is increasingly used as a surrogate for dialysis adequacy; however, its accuracy has been debated [14]. Studies by Lindsay RM et al., and McIntyre CW et al., have indicated a moderate correlation between OCM and calculated Kt/V [15,16], while Sabry AA et al., highlight significant discrepancies between these measurements [14].

Zhang L et al., highlight the importance of monitoring dialysis dose in each session due to session-to-session variation impacting treatment quality. Their study, conducted in China, demonstrated that online monitoring with Adimea®, a UV spectroscopy-based system for spent dialysate analysis, improved and maintained dialysis adequacy [3]. Notably, they found that patients with a baseline Kt/V <1.20 showed a significant increase to reach an adequacy level >1.20 with Adimea® monitoring [3]. This aligns with present study which emphasises on optimising treatment effectiveness and suggests that tools for real-time dialysis dose assessment can be valuable.

The frequency of alarm muting varied widely across sessions (M±SD=2.02±2.858 times per session), emphasising the need for standardised protocols. Even though alarm systems are crucial for patient safety, present study findings suggest that carefully managed alarm muting may not necessarily affect treatment effectiveness. However, concerns remain regarding patient safety and the potential for missing critical alerts. Prior research emphasises that effective HD is influenced not just by clearance metrics but also by haemodynamic stability and individualised patient responses [17].

Present study findings highlight the complex relationship between the frequency of alarms and dialysis adequacy. This highlights the importance of implementing effective alarm management protocols in dialysis centres—protocols that help staff respond quickly when something is truly wrong while also minimising distractions from unnecessary alerts.

Limitation(s)

This study had several limitations. First, the single-centre nature of present study and the relatively small sample size may limit the generalisability. Larger multicentre studies are required to validate these findings. In addition, the uneven gender distribution in present study might not represent the broader dialysis population.

Future research should investigate whether these findings can be replicated in larger, more diverse patient populations across multiple dialysis centres. Studies can be conducted to explore the specific types of interventions that trigger alarms and their impact on dialysis adequacy, using OCM data to track changes in Kt/V. Furthermore, studies are needed to determine the optimal balance between alarm sensitivity and specificity in HD machines.

CONCLUSION(S)

This study provides evidence of a complex relationship between alarm frequency and dialysis adequacy. While frequent alarm muting is associated with slightly improved treatment effectiveness, further research is needed to fully understand the underlying mechanisms and optimise alarm management strategies in HD, potentially utilising OCM to improve dialysis monitoring and outcomes.

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REFERENCES

[1] Kliger AS. Maintaining safety in the dialysis facility. Clin J Am Soc Nephrol. 2015;10(4):688-95.
[2] Bach TA, Berglund LM, Turk E. Managing alarm systems for quality and safety in the hospital setting. BMJ Open Qual. 2018;7(3):e000202. Doi: 10.1136/bmjoq-2017-000202.
[3] Zhang L, Liu W, Hao C, He Y, Tao Y, Sun S, et al. Ensuring hemodialysis adequacy by dialysis dose monitoring with UV spectroscopy analysis of spent dialyzate. Int J Artif Organs. 2022;45(4):351-59.
[4] Kuhlmann U, Goldau R, Samadi N, Graf T, Gross M, Orlandini G, et al. Accuracy and safety of online clearance monitoring based on conductivity variation. Nephrol Dial Transpl. 2001;16(5):1053-58.
[5] Grangé S, Hanoy M, Le Roy F, Guerrot D, Godin M. Monitoring of hemodialysis quality-of-care indicators: Why is it important? BMC Nephrol. 2013;14(1):109.
[6] Stiller S, Al-Bashir A, Mann H. On-line urea monitoring during hemodialysis: A review. Saudi J Kidney Dis Transpl. 2001;12(3):364-74.
[7] Mohan S, Madhrira M, Mujtaba M, Agarwala R, Pogue V, Cheng JT. Effective ionic dialysance/blood flow rate ratio: An indicator of access recirculation in arteriovenous fistulae. ASAIO J. 2010;56(5):427-33.
[8] Aslam S, Saggi SJ, Salifu M, Kossmann RJ. Online measurement of hemodialysis adequacy using effective ionic dialysance of sodium- A review of its principles, applications, benefits, and risks. Hemodial Int. 2018;22(4):425-34.
[9] Estudillo-Valderrama MA, Talaminos-Barroso A, Roa LM, Naranjo-Hernández D, Reina-Tosina J, Aresté-Fosalba N, et al. A distributed approach to alarm management in chronic kidney disease. IEEE J Biomed Health Inform. 2014;18(6):1796-803.
[10] Somji SS, Ruggajo P, Moledina S. Adequacy of hemodialysis and its associated factors among patients undergoing chronic hemodialysis in Dar es Salaam, Tanzania. Int J Nephrol. 2020;2020(1):9863065.
[11] Mansur A, Saleem S, Mahmood A, Rasool Z. Assessment of hemodialysis adequacy: Correlation between online clearance monitoring and single pool Kt/V. Prof Med J. 2020;27(11):2407-13.
[12] Daugirdas JT, Tattersall JE. Automated monitoring of hemodialysis adequacy by dialysis machines: Potential benefits to patients and cost savings. Kidney Int. 2010;78(9):833-35.
[13] Seddik AA, Alalawi F, Dela M, Perez C, Rambhau R, Alhadari A. Online Kt/V (Urea) monitoring in maintenance hemodialysis patients, single center experience. Ain Shams Med J. 2024;75(2):479-87.
[14] Sabry AA, Alsaran K, Yehia A, El-Shafey EM, Al-Yousef A. Hemodialysis adequacy: A comparative multicenter study between OCM and calculated Kt/V from two centers in the Gulf. J Nephrol Ther. 2011;1(108):2161-0959.
[15] Lindsay RM, Bradfield E, Rothera C, Kianfar C, Malek P, Blake PG. A comparison of methods for the measurement of hemodialysis access recirculation and access blood flow rate. ASAIO J. 1998;44(1):54.

[16] McIntyre CW, Lambie SH, Taal MW, Fluck RJ. Assessment of haemodialysis adequacy by ionic dialysance: Intra-patient variability of delivered treatment. Nephrol Dial Transplant. 2003;18(3):559-63.

[17] Rajagopalan A, Raja N, Mohan G. Dialysis adequacy: A cross-sectional study to assess the reliability of the online clearance monitor to measure dialysis dose. Cureus. 2024;16(1):e52328.

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