Original Article

Appropriate Dialyzer Selection among Patients on Hemodialysis

Dialyzer Selection among Patients on Hemodialysis

Shahid Anwar[1], Sajad Ahmad[1], Hafiz Tahir Usman[1], Mateen Akram[2] and Abad-ur-Rehman Awan[5]

ABSTRACT

Objective: To determine the appropriate dialyzer type for the individual patient which is effective for adequate hemodialysis?

Study Design: Cross-sectional study

Place and Duration of Study: This study was conducted at the Department of Nephrology, Sir Ganga Ram Hospital, Lahore from 1st October 2021 to 2nd November 2021.

Materials and Methods: Seventy adult dialysis patients undergoing regular hemodialysis at our dialysis center were included in the study. Patients with acute renal failure were excluded. Biodata of patients including gender, age, height, weight, and BMI were recorded, total body water was calculated using Watson's equation. "K" was be calculated by rearranging the Kt/V=1.4 equation. In-vivo to in-vitro conversion is done by dividing the value of "K" by 0.85.

Results: The mean age was 48.09±11.63 years, mean weight was 62.06±11.86 kg, mean BMI was 23.63±4.45 kg/m^2 and mean TBW was 34.18±5.31 L. At QB of 250ml/min, 300 ml/min, and 300 – 400 ml/min, TBW mean value helped in the choice of dialyzer.

Conclusion: Hemodialysis should be performed after the selection of an appropriate dialyzer and blood flow rate to prevent inadequate hemodialysis.

Key Words: Dialyzer, Hemodialysis, Kt/V

Citation of article: Anwar S, Ahmad S, Usman HT, Akram M, Awan AR. Appropriate Dialyzer Selection among Patients on Hemodialysis. Med Forum 2022;33(2):142-146.

INTRODUCTION

Hemodialysis (HD) is the treatment of choice for end-stage renal disease (ESRD) patients if renal transplantation is not possible due to any cause.[1] HD not only improves the quality of life but also reduces morbidity and mortality as compared with chronic kidney disease (CKD) patients who refuse HD.[2] Offering HD to ESRD is not enough as HD should be adequate. Adequacy of dialysis is deciding factor for the reduction of morbidity and mortality among these patients.[3]

Adequacy of dialysis is measured in terms of Kt/V and urea reduction ratio (URR) proposed by National Kidney Foundation-Kidney Disease Outcomes Quality Initiative guidelines.[4]

Frank Gotch and John Sargent first introduced the idea of Kt/V as a measurement tool for the dose of dialysis after analyzing data from the National Cooperative Dialysis Study.[5] Kt/V is a so-called "dimensionless ratio in which (K) is dialyzer urea clearance, treatment time (t), divided by the urea distribution volume (V).[6] There are multiple variants of Kt/V; spKt/V (single pool), eKt/V (equilibrated), and stdKt/V (standardized). The most common formula used for dialysis dose is spKt/V but it does not incorporate post-treatment rebound. Rebound is a major issue when clearance rates are high and/or treatment times are short; spKt/V should be converted into eKt/V that incorporates rebound issues.[7] Several formulas are available online to translate spKt/V to eKt/V as it is not an easy task for clinicians to do it manually. The target recommended dose should be a spKt/V of 1.4 or eKt/V of 1.2. A weekly dose of dialysis is measured by stdKt/V (Online calculator); NKF-DOQI Guidelines recommend a minimum stdKt/V of 2.0 per week and is roughly equivalent to a spKt/V of 1.2.[8]

The most important factor of Kt/V is K; which represents the dialyzer clearance, the rate at which blood clears its solutes as it passes through the dialyzer, expressed in milliliters per minute (mL/min). Increasing the blood flow rate (QB), clearance (K) will increase linearly initially but as QB reaches near dialysate flow rate (QD) there will be no additional increase of

[1.] Department of Nephrology, Fatima Jinnah Medical University/Sir Ganga Ram hospital, Lahore.
[2.] Department of Nephrology, Shaikh Zayed Postgraduate Medical Institute Lahore.
[3.] Department of Nephrology, Punjab Institute of Cardiology, Lahore.

Correspondence: Dr. Shahid Anwar, Associate Professor, Department of Nephrology, Fatima Jinnah Medical University/Sir Ganga Ram hospital, Lahore.
Contact No: 0333-4219474
Email: nephroshahidanwar73@hotmail.com

Received: December, 2021
Accepted: January, 2022
Printed: February, 2022

clearance. However, this ability of the dialyzer for the removal of solutes (K) is proportional to the mass transfer area coefficient (KoA). KoA is simply a product of dialyzer membrane permeability (Ko) and the membrane surface area (A). KoA is specific to urea (or any other solute used for measurement) and is independent of QB and QD. The greater the KoA, the greater will be the clearance of urea and other toxins, and the greater will be delivered dialysis dose when expressed in terms of Kt/V. The KoA of a dialyzer is checked by in vitro aqueous solutions usually provided on the dialyzer datasheet by the manufacturer.[9] Usually, in vitro KoA is almost 20% less as compared to in vivo calculations due to the actual performance of dialyzer on patient's blood that contains various proteins and red blood cells.[10]

There are multiple factors of inadequate dialysis or in others words failure to achieve target Kt/V. Studies have proved that errors in calculating V and/or V greater than 40L will lead to inadequate dialysis.[1]. The total duration of the hemodialysis session of fewer than 4 hours will greatly affect Kt/V; usually the shortcoming of dialysis technicians or the patient's desire of ending the hemodialysis session early[12]. Most importantly "K" is not achieved as desired because of low QB due to Arteriovenous (AV) fistula stenosis leading to Access recirculation. Suboptimal use of dialyzer with low KoA and surface area less than 1.4 m^2 affects "K" of Kt/V resulting in inadequate hemodialysis.[13] It is now a well-known fact that Standardized hemodialysis prescriptions (fixed QB, QD, and dialyzer type) affect the adequacy of hemodialysis in most patients.[14]

In Pakistan where the annual incidence of new cases of end-stage renal disease (ESRD) is >100 per million population[15], most of the patients receive twice-weekly hemodialysis usually in private setups but some Government-owned hospitals offer thrice-weekly hemodialysis free of cost.[16] Dialysis session duration is usually 3 to 3.5 hours in most dialysis centers because of the increase in patient burden. However tertiary care hospitals where dialysis centers are under the care of nephrologists, offer 4 hours duration hemodialysis[17]. Most dialysis centers follow standardized hemodialysis prescriptions; with only one or two types of dialyzers, 250-350 ml/min QB and QD of 500 ml/min.[18] Alarmingly 61% of hemodialysis patients are under dialyzed.[19] No serious effort has been made so far in the local nephrology community to choose the appropriate dialyzer for adequate hemodialysis. Now a day's wide variety of dialyzers is available in Pakistan where one can choose a dialyzer according to body volume of distribution of urea and QB.[20]

This research work is designed to determine the appropriate dialyzer type for the individual patient which is effective for adequate hemodialysis.

MATERIALS AND METHODS

This cross-sectional descriptive study was conducted in the hemodialysis unit of the Nephrology department at Fatima Jinnah Medical University/ Sir Ganga Ram hospital, Lahore from 1st October 2021 to 2nd November 2021. All adult dialysis patients (70 in number) undergoing regular hemodialysis at our dialysis center were included in the study. Patients with acute renal failure were excluded. After taking institutional ethical board permission and informed consent, biodata of patients including gender, age, height, weight, and BMI were recorded.

Dialyzer Selection procedure: To determine the dialyzer that will provide a target Kt/V of 1.4, the following steps were followed.[21]

1. Calculate the total body water (TBW = Urea volume of distribution) by using the Watson equation that will give the value of "V". (Suppose it is 40,000 ml).
2. Standard 4 hours hemodialysis session time will give "t" of 240 minutes. (fixed)
3. K will be calculated by rearranging Kt/V equation: $K \times 240 = 1.4 \times 40{,}000$ or $K = 1.4 \times 40{,}000/240$ $K = 233$ ml/min
4. In-vivo to In-vitro conversion = 233/0.85 = 274 ml/min (fixed factor of 0.85)
5. A dialyzer with published in-vitro urea clearance of 274 ml/min at a QB of 200 ml/min, 250ml/min, 300ml/min, and QD 500 ml/min were selected based on data provided by the manufacturer on the dialyzer specification sheet.

These dialyzers were provided by hospital administration free of cost to patients. Almost all dialyzers specification sheets mentioned the value of "K" at QB of 200 and 300 ml/min, but the value of "K" at 250ml/min is not provided by the manufacturer so the average value was calculated.

Results were analyzed using SPSS 21 (24.0). Qualitative variables were described as percentages and numbers. Quantitative variables were described as means [± SD] for parametric variables or medians (minimum-maximum), for non-parametric variables. The chi-square and Pearson's correlation test were applied to take a p-value less than 0.05 as significant.

RESULTS

The mean age was 48.09±11.63 years, mean weight was 62.06±11.86 kg, mean BMI was 23.63± 4.45 kg/m^2, and mean TBW was 34.18±5.31 liters. The frequency distribution of different dialyzers at QB of 250 ml/min, 300 ml/min, and 300–400 ml/min is shown in Table 2.

When correlation was checked with choice of dialyzers concerning the weight of patient at QB of 250 ml/min, 300 ml/min, and 300 – 400 ml/min, no statistical significance was found with a p-value of 0.096, 0.893, and 0.961 respectively. When correlation was checked with choice of dialyzers concerning BMI of the patient at QB of 250 ml/min, 300 ml/min, and 300–400 ml/min, no statistical significance was found with a p-value of 0.247, 0.195, and 0.215 respectively. When correlation was checked with choice of dialyzers concerning TBW of the patient at QB of 250 ml/min, 300 ml/min, and 300 – 400 ml/min, statistical significance was found with a p-value of 0.011, 0.003, and 0.005 respectively. At QB of 250ml/min, 300 ml/min, and 300 – 400 ml/min, TBW mean value helped in the choice of dialyzer as shown in Table 3.

Table No.1: Dialyzer's specification sheet

Surface area	**Model**	**Manufacturer**	**K at QB 200** ml/min	**K at QD 250** ml/min (average)	**K at Qb 300** ml/min
1.1m^2	11 L	Nipro	188	215	242
1.3m^2	13 L	Nipro	192	222	251
1.4m^2	FX8	Fresenius	191	223	254
1.5m^2	15 L	Nipro	194	228	261
1.6m^2	F7	Fresenius	Not mentioned	Not mentioned	247
1.7m^2	17L	Nipro	195	231	267
1.8m^2	F8	Fresenius	Not mentioned	Not mentioned	252
1.8m^2	FX10	Fresenius	193	227	261
1.9m^2	19 L	Nipro	196	235	273
2.1m^2	21 L	Nipro	197	237	277

Table No.2: Frequency distribution of different dialyzers

Surface area	**Model**	**Manufacturer**	**QB 250**	**QD300**	**QB 300-400**
1.1m^2	11 L	Nipro	21 (30%)	44 (62.9%)	44 (62.9%)
1.3m^2	13 L	Nipro	6 (8.6%)	2 (2.9)%	2 (2.9%)
1.4m^2	FX8	Fresenius	-	-	-
1.5m^2	15 L	Nipro	2 (2.9%)	-	-
1.6m^2	F7	Fresenius	-	1 (1.4%)	1 (1.4%)
1.7m^2	17L	Nipro	-	-	-
1.8m^2	F8	Fresenius	-	-	-
1.8m^2	FX10	Fresenius	-	2 (2.9%)	2 (2.95)
1.9m^2	19 L	Nipro	6 (8.65)	8 (11.4)	8 (11.4%)
2.1m^2	21 L	Nipro	4 (5.7%)	5 (7.1%)	13 (18.6%)
		Didn't fit in any	31 (44.3%)	8 (11.4%)	-

Table No.3: Choice of dialyzer based on Total body water and Blood flow rates

Surface area	**Model**	**Manufacturer**	**QB 250**	**QD300**	**QB 300-400**
1.1m^2	11 L	Nipro	27.8±2.1	30.8±3.4	30.8±3.4
1.3m^2	13 L	Nipro	31.7±0.2	35.6±0.2	35.6±0.2
1.4m^2	FX8	Fresenius	-	-	-
1.5m^2	15 L	Nipro	33.1±0.1	-	-
1.6m^2	F7	Fresenius	-	36±0	36±0
1.7m^2	17L	Nipro	-	-	-
1.8m^2	F8	Fresenius	-	-	-
1.8m^2	FX10	Fresenius	-	37.8±0.4	37.8±0.4
1.9m^2	19 L	Nipro	34±0.2	39.1±0.5	39.1±0.5
2.1m^2	21 L	Nipro	34.3±0.4	40.3±0.1	41.5±1.4
		Didn't fit in any	39±2.7	42.2±1.3	-

DISCUSSION

To achieve adequate HD, four factors play a crucial role, QB, QD, duration of HD, and efficiency of the dialyzer.[9]It is well-documented fact that increasing QD can give better clearance[22] but in routine HD procedure QD plays the least important role because standard dialysate concentrate comes in the packaging that can support 4 hours duration of HD if QD is set at 500ml/min. In Pakistan most manufacturers prepare dialysate concentrates according to this idea. If we want to increase QD to 600-700 ml/min, two dialysate cans will be used for that patient which is not cost-effective.

So, achieving adequate HD by increasing QD is not a practical option.

Increasing the duration of HD can increase Kt/V[13], however, increasing time from standard 4 hours to 5 or 6 hours is also not a very useful technique because of 2 major reasons. Firstly, more than 4 hours of dialysis requires 2 dialysate cans and secondly HD units can manage 3 shifts of 4 hours duration back-to-back starting from 8 am to 10pm with almost 45 minutes time requirement for sterilization of machines after the end of every shift. Increasing the time of HD can be an option in the last shift for some selected individuals but patients on maintenance HD for many years usually don't find this option suitable for them as they are bound socially in other activities.

QB and choice of dialyzers are two factors that can be managed with ease. QB depends upon the AV fistula blood flow. A fully functional fistula should have a minimum blood flow of 800ml/min.[23,24] If the adequacy of HD is not achieved with a standard QB of 250ml/min then it can be managed by increasing QB to 300ml/min or even more. But high QB requires a fully developed fistula body having a measurement of at least 4mm in diameter.[25] However, fistulas with inflow/outflow stenosis and partial thrombosis may not allow high QB required for adequate HD. Choosing a dialyzer with high efficiency can be an alternative provided a full range of dialyzers are available.[26]

In this study dialyzers were selected according to patient TBW and Kt/V target of 1.4, keeping two factors constant, QD of 500ml/min and duration of HD (t) 4 hours as shown in table 2. To select a dialyzer for a patient, one should know the condition of AV fistula and maximum QB that can be achieved without triggering pre/post-pump arterial pressure alarms. If AV fistula only tolerates QB of 250ml/min then patients with TBW <34.3L can have the choice of dialyzers shown in table 3. If TBW is more than 39L then at QB of 250 ml/min 44.3% of patients will not achieve target Kt/V. That could be a reason that previous studies showed inadequate HD with dialyzers with a surface area of less than $1.4m^2$. If AV fistula tolerates high QB then dialyzers can be selected according to individual's TBW values (Table 3) which can be calculated easily by Watson's equation. Once appropriate dialyzer selection is done then the performance of the dialyzer at the given QB should be checked periodically by calculating the Urea reduction ratio and achieved Kt/V as proposed by KDIGO guidelines.[6]

CONCLUSION

Hemodialysis should be performed after the selection of an appropriate dialyzer and blood flow rate to prevent inadequate hemodialysis.

Author's Contribution:

Concept & Design of Study:	Shahid Anwar
Drafting:	Sajad Ahmad, Hafiz Tahir Usman
Data Analysis:	Mateen Akram, Abad-ur-Rehman Awan
Revisiting Critically:	Shahid Anwar, Sajad Ahmad
Final Approval of version:	Shahid Anwar

Conflict of Interest: The study has no conflict of interest to declare by any author.

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