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Factors influencing the quality of intermittent renal replacement therapy in critically ill patients

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ABSTRACT

Introduction: Multiple factors influence the effectiveness of intermittent renal replacement therapy in critically ill patients, in which the role of nursing staff is fundamental.

Objective: To describe the factors influencing the quality of intermittent renal replacement therapy in critically ill patients.

Material and Method: We conducted a descriptive retrospective study of 413 intermittent renal replacement therapy sessions performed in intensive care units between January and December 2018. Variables analysed included age, sex, admission diagnosis, technique-related factors and factors modifying prescribed dialysis time.

Results: Mean age was 65±13 years; 78.7% were men. The main cause of admission was septic shock (35.1%). Intermittent haemodialysis was the most common technique (52.1%). The most frequent vascular access was a temporary jugular catheter (37.8%), whose dysfunction was identified as a factor associated with poorer session quality in 37% of cases ($p<0.015$). Other relevant factors were reduced effective haemodialysis time (27%, $p<0.000$) and definitive session suspension (15.5%, $p<0.002$). Mean Kt was 48.6±23 L/min, and 35% of sessions were below the minimum recommended Kt.

Conclusion: Dialysis quality in critically ill patients undergoing intermittent renal replacement therapy depends on non-modifiable factors such as clinical condition, and modifiable factors such as early detection of vascular access dysfunction, causes of session suspension and intradialytic adjustments to improve tolerance and prevent complications.

Keywords: acute kidney injury; dialysis quality; ionic dialysance; intermittent renal replacement therapy; dialysis dose; intensive care unit.

RESUMEN

Factores que influyen en la calidad de la terapia sustitutiva renal intermitente en pacientes en estado crítico

Introducción: En la terapia renal sustitutiva intermitente del paciente crítico, intervienen múltiples factores que condicionan la eficacia dialítica, donde el papel de la enfermera es fundamental.

Objetivo: Describir los factores que influyen en la calidad de la terapia sustitutiva renal intermitente en pacientes en estado crítico.

Material y Método: Estudio descriptivo retrospectivo de 413 sesiones de terapia sustitutiva renal intermitente, realizadas en unidades de cuidados intensivos desde enero hasta diciembre del 2018, donde se analizaron variables como: edad, sexo, diagnóstico de ingreso, factores relacionados con la técnica y los que modifican el tiempo prescrito de diálisis.

Resultados: Edad media 65±13 años; con predominancia de hombres (78,7%); la principal causa de ingreso fue shock séptico (35,1%), tipo de técnica hemodiálisis intermitente, (52,1%), acceso vascular catéter temporal yugular (37,8%), cuya disfunción se identificó como uno de los factores asociados a una menor calidad de las sesiones en un 37% ($p<0,015$). Otros factores relevantes fueron: disminución del tiempo efectivo de hemodiálisis 27% ($p<0,000$) y suspensión definiti-

va de las sesiones 15,5% (*p*<0,002). El Kt medio obtenido fue 48,6 l/min±23 litros y el 35% de las sesiones estuvieron por debajo del Kt mínimo recomendado.

Conclusiones: La calidad de diálisis en el paciente crítico con tratamiento sustitutivo renal intermitente depende de factores no modificables como el estado clínico del paciente y modificables como la detección precoz de alteraciones del funcionamiento del acceso vascular, causas de suspensión definitiva de la sesiones y ajustes intradiálisis para mejorar la tolerancia a la técnica y prevenir las complicaciones.

Palabras clave: lesión renal aguda; calidad de diálisis; dialisancia iónica; tratamiento sustitutivo renal intermitente; dosis de diálisis; unidad de cuidados intensivos.

INTRODUCTION

Acute kidney injury (AKI) is a frequent complication, affecting approximately 5–10% of hospitalised patients and up to 40% of patients admitted to intensive care units (ICUs) in Spain[1-3]. Approximately 4–5% of patients require renal replacement therapy (RRT), which is associated with high mortality, estimated at around 30%[3]. RRT includes continuous renal replacement therapy (CRRT) and intermittent haemodialysis (IHD), either in conventional form or adapted as slow low-efficiency dialysis (SLED)[3,4]. The main risk factors for requiring RRT include advanced age, male sex and the presence of sepsis[3,4].

In renal replacement therapy, achieving an adequate delivered dose with good treatment tolerance is a recognised quality objective[5,6]. Accordingly, international haemodialysis clinical practice guidelines (American, European, Canadian, Australian and Spanish) recommend monitoring both the prescribed and delivered dialysis dose using Kt/V, based on the urea kinetic model (UKM)[7]. This was later complemented by measurement through ionic dialysance using online clearance monitoring (OCM), expressed as Kt, where K represents dialyser urea clearance and t the programmed session duration. This system allows daily monitoring of the delivered dialysis dose[7,8]. Since 1999, Lowrie et al.proposed Kt as a marker of dialysis dose and mortality, recommending a minimum Kt of 40–45 L in women and 45–50 L in men[9].

Much less evidence is available to establish the optimal RRT dose in critically ill patients. The KDIGO international guideline recommends that such patients receive at least the same dose as chronic haemodialysis patients (Kt/V = 1.3 per session), delivered over three sessions per week[10].

Furthermore, the dialysis dose is influenced by interactions among several variables, including membrane surface area and permeability, which must meet specific requirements for solute and fluid removal, blood flow (Qb) and dialysate flow rate (Qd)[7,11].

Multiple factors may negatively affect therapy performance, such as inadequate Qb limited by vascular access dysfunction (poor flow, high recirculation), incorrect Qd, improper circuit priming, dialyser fibre clotting, reduction of programmed treatment time due to interruptions for vascular access manipulation, frequent alarms, premature session termination due to intolerance or haemodynamic instability[5,12,13]. All these aspects are directly monitored and managed by nursing staff.

Intermittent renal replacement therapy (IRRT) is therefore a critical component of the management of critically ill patients with AKI. The proper delivery and quality of dialysis dose are key determinants of treatment efficacy, patient recovery and haemodynamic stability. In this context, the nurse plays a fundamental role, being responsible for continuous monitoring, control and supervision of IRRT, including session-by-session Kt monitoring, detection of irregularities and coordination with the attending physician to implement necessary treatment adjustments, ultimately influencing patient outcomes.

Therefore, the aim of this study was to determine the factors influencing the quality of intermittent renal replacement therapy in critically ill patients.

MATERIAL AND METHOD

Study Design

Descriptive, cross-sectional, retrospective study.

Population and Setting

A total of 413 IRRT sessions (IHD/SLED) performed in 91 critically ill patients with acute kidney injury or chronic haemodialysis dependence admitted to the surgical, medical and coronary ICUs of Hospital Clínic de Barcelona (Barcelona, Spaion) during 2018 were analysed. Data were obtained from the Nefrolink® electronic registry.

Study Variables

Patient characteristics included sex, age, admission diagnosis and ICU type (surgical, coronary, or medical ICU: respiratory, hepatic and internal medicine). Treatment-related parameters included therapy modality (IHD/SLED), type and location of vascular access (native or prosthetic arteriovenous fistula; non-tunnelled jugular or femoral central venous catheter; tunnelled jugular catheter), prescribed dialysis time, dialyser type, blood flow (Qb), dialysate flow (Qd) and anticoagulation. All sessions were performed using Fresenius 5008 monitors with OCM biosensors, enabling automatic Kt measurement. An adequate Kt was defined as 45–50 L in men and 40–45 L in women, as recommended by clinical practice guidelines[8,24,27].

Factors affecting dialysis quality included vascular access dysfunction, defined as inability to obtain or maintain Qb≥300 mL/min during IHD within the first 60 minutes, despite corrective manoeuvres, with need for line reversal

and recirculation >20%; AVF infiltration or haematoma preventing re-cannulation; Qb reduction >20 mL/min from prescribed; effective dialysis time reduction >15 min in IHD or >30 min in SLED; session termination ≥30 minutes before completion; partial or total extracorporeal circuit clotting; haemodynamic instability; use of vasoactive drugs; and logistical factors (nursing availability, diagnostic procedures > 60 min, monitor malfunction).

Data Collection

Data were obtained from SAP® and Nefrolink® electronic records between March and June 2019 and recorded in an anonymised Excel database.

Statistical Analysis

Quantitative variables were analysed using mean ± standard deviation and median (interquartile range). Qualitative variables were summarised as absolute and relative frequencies (percentages). To identify associations between qualitative variables and achievement of the minimum dialysis dose (Kt), bivariate analysis was performed using the chi-square test (Fisher's exact test for expected frequencies <5), considering a p value <0.05 as statistically significant. Subsequently, a multivariable analysis was conducted using binary logistic regression to identify factors independently associated with Kt below the recommended value. Adjusted odds ratios (ORs) with their corresponding confidence intervals and p values were calculated. Variables included in the model were selected based on statistical significance in the bivariate analysis and clinical relevance.

All data were processed and analysed using SPSS® (Statistical Package for the Social Sciences), version 24.0.

Ethical considerations

The study was approved by the Research Ethics Committee for Medicinal Products (CEIm) of Hospital Clínic de Barcelona (approval number: HCB 2018/0955). The study was conducted in accordance with the principles of the Declaration of Helsinki, as revised at the October 2013 General Assembly in Fortaleza, Brazil, and in compliance with Spanish Organic Law 15/1999 of 13 December and its May 2018 amendment on the Protection of Personal Data (LOPD).

RESULTS

A total of 413 IRRT sessions were analysed, performed in 91 critically ill patients admitted to the ICU. Among them, 52.8% (n=218) had acute kidney injury and 47.2% (n=195) were chronic haemodialysis patients. Of all sessions, 52.1% (n=215) were performed as IHD and 47.9% (n=198) as SLED; the highest proportion of sessions (44.5%, n=183) took place in the surgical ICU.

The characteristics of the study sessions are shown in **table 1.** Mean patient age was 65±13 years, and 78.7% were men (n = 325). The most frequent admission diagnosis was septic shock (35.1%, n=145), followed by respiratory failure (24.2%, n=100). Regarding dose-related parameters, the most commonly used vascular access was the non-tunnelled jugular venous catheter (37.8%, n=156). Mean session duration was 360 ± 180 minutes. The most frequently used dialyser was Helixone® (1.0–1.4 m²) in 95% of sessions (n=395). Mean dialysate flow rate (Qd) was 300±75.6 mL/min, and mean blood flow rate (Qb) was 250±82 mL/min.

Table 1. Characteristics of the dialysis sessions.

Variables	n	%
Sex		
• **Male**	**325**	**78.7**
• Female	88	21.3
Reason for ICU Admission		
• **Septic shock**	**145**	**35.1**
• Respiratory failure	100	24.2
• Post-surgical	**77**	**18.6**
• Cardiogenic shock	**47**	**11.4**
• Hypovolaemic shock	**21**	**5.1**
• Polytrauma	**23**	**5.6**
Type of Kidney Failure		
• CKD	195	**47.2**
• AKI	**218**	**52.8**
Type of Renal Replacement Therapy		
• **IHD**	**215**	**52.1**
• SLED	198	47.9
Source ICU		
• Surgical ICU	183	44.3
• Medical ICU	172	41.7
• Coronary ICU	58	14.0
Vascular Access		
• **Non-tunnelled jugular CVC**	**156**	**37.8**
• Non-tunnelled femoral CVC	94	22.8
• Tunnelled jugular CVC	86	20.8
• AVF	67	16.2
• Prosthetic AVF	10	2.4
Dialyser Type		
• **Helixone® (1.0–1.4 m²)**	**395**	**95.6**
• Cellulose triacetate	16	3.9
• Polypropylene 1.7 m²	2	0.5
Blood Flow (Qb)		
• <250 mL/min	206	49.9
• 250–400 mL/min	207	50.1

CKD: Chronic kidney disease; **AKI:** Acute kidney injury; **IHD:** Intermittent haemodialysis; **SLED:** Slow low-efficiency dialysis; **CVC:** Central venous catheter; **AVF:** Arteriovenous fistula.

The mean Kt achieved was 48.6±23 L in 93.2% of sessions (n=385); Kt was not recorded in 6.8% (n=28). Regarding recommended targets, 33.6% of men (n=109) had Kt values <45 L, and 39.8% of women (n=35) were <40 L. No statistically significant difference was found between sexes in achieving the minimum Kt recommended by KDIGO guidelines (p>0.339).

Table 2. Factors associated with failure to achieve the recommended minimum dialysis dose (Kt)

Variables	n	%	OR	95%CI	p-value
Vascular access dysfunction	**74**	**17.7**	**1.89**	**1.13–3.15**	**0.015**
Recirculation >20%	27	6.5	0.85	0.57–1.28	0.461
Catheter change	15	3.6	0.93	0.31–2.78	0.899
Line reversal	**34**	**8.2**	**2.02**	**1.16–3.50**	**0.011**
Qb modification	40	9.7	0.49	0.38–1.59	0.782
Reduction of effective dialysis time > 15 min in IHD	53	13.0	1.26	0.70-2.28	0.436
Reduction of effective dialysis time >30 in SLED	**58**	**14.0**	**2.90**	**1.64-5.11**	**0.000**
Definitive session termination ≥ 30 min before ≥ 30 min before	**64**	**15.5**	**2.28**	**1.33-3.91**	**0.002**
Haemodynamic instability	217	52.5	1.16	0.77–1.74	0.461
Heparin-free sessions	150	36.3	0.82	0.53–1.24	0.344
Total extracorporeal circuit clotting	61	14.8	1.47	0.84-2.56	0.191
Organisational factors					
Lack of nursing staff	9	2.18	2.38	0.63–9.01	0.287
Session suspension due to diagnostic tests >60 min	2	0.5	0.98	0.96–1.00	0.121
Monitor malfunction ≥ 60 min	4	1.0	1.01	1.00–1.30	0.303
Sessions without clinical cor technical complications	35	8.5	1.34	0.84–2.12	0.251

IHD: Intermittent haemodialysis; **SLED:** Slow low-efficiency dialysis; **Qb:** Blood flow rate; **OR:** Odds ratio; **CI:** Confidence interval.

As shown in **table 2**, failure to reach the recommended minimum Kt was significantly associated with catheter dysfunction, line reversal, reduction of treatment time >30 minutes during SLED, and definitive session termination.

Conversely, session interruption due to diagnostic procedures (OR, 0.98; 95%CI, 0.96–1.00) and monitor malfunction (OR, 1.01; 95%CI, 1.00–1.30) were not significantly associated with suboptimal Kt ($p>0.05$). Although these estimates suggest potentially relevant clinical trends—particularly regarding session interruption—no conclusive association could be established in this sample **(table 2)**.

Use of IHD vs SLED was associated with a higher prevalence of hypotension and arrhythmias (OR, 4.74, $p<0.05$), indicating greater haemodynamic instability with IHD. Regarding anticoagulation, 36.3% of sessions (n=150) were performed without heparin, and extracorporeal circuit clotting occurred in 14.8% of sessions (n=61). However, heparin use was not significantly associated with a lower rate of circuit clotting (39% [n=44] vs 22% [n=17]; p=0.153).

Other logistical factors (interruption for diagnostic procedures, monitor malfunction, and staff shortage) accounted for reduced dialysis time in 3.6% of sessions (n=15; $p<0.001$). Definitive session termination was required in 15.5% of sessions (n=64), with hypotension and arrhythmias being the most frequent cause (6.5%, n=27), followed by complete extracorporeal circuit clotting (5.8%, n=24) **(table 3).**

DISCUSSION

In our centre, critically ill patients admitted to the ICU who require IRRT constitute a population in which the primary reason for admission is septic shock, predominantly male and older than 65 years. These are non-modifiable risk factors, as described in other studies conducted in critically ill populations[14-16].

Regardless of whether IHD or SLED is prescribed, the primary objective is the quality of therapy, which must be both effective[5,6] and haemodynamically well tolerated[17]. Therefore, a reliable indicator is required to closely monitor the delivered dialysis dose, determine whether it is adequate, and identify factors leading to suboptimal dosing[13,18,19], as well as aspects that can be modified through nursing interventions[19,21].

In the management of critically ill patients, non-modifiable factors such as haemodynamic instability[17,25] and sepsis[3,14,16] have been correlated with poorer tolerance of the prescribed therapy[17,25].

In our cohort, 52% of patients presented haemodynamic instability, with a clear association between hypotension and arrhythmias during dialysis. Although hypotension occurred in both treatment groups, patients receiving SLED exhibited a lower frequency of these complications compared with those receiving IHD, suggesting that treatment modality plays a key role in patient tolerance.

Table 3. Causes of definitive session termination.

Variables	n	%
Hypotension and arrhythmias	27	6.5
Total extracorporeal circuit clotting	24	5.8
Accidental removal of catheters and needles	2	0.5
Vascular access dysfunction	6	1.5
AVF infiltration and haematoma	1	0.2
Monitor malfunction	1	0.2
Diagnostic procedures	2	0.5
Allergic reaction to dialyser	1	0.2
Total	**64**	**15.5**

AVF: Arteriovenous fistula.

Schäffl et al.[28]. demonstrated that patient severity and treatment-related complications are associated with reduced dialysis dose, particularly in patients with septic shock. Similarly, Santos et al.[29]. concluded that intradialytic haemodynamic instability interferes with achieving dialysis targets and requires immediate nursing interventions. Ross et al.[20] further showed that continuous clearance monitoring enables maintenance and achievement of adequate dialysis dosing.

In our study, dialysis dose was assessed using Kt measured by ionic dialysance, enabled by conductivity sensors integrated into dialysis monitors, allowing real-time assessment of urea balance throughout each session[21,22]. A similar study reported that Kt-based dose estimation in critically ill patients allows real-time monitoring and adjustment of IRRT[23].

There is broad consensus that dialysis dose is a crucial determinant of patient prognosis; however, substantial inter-individual and inter-session variability exists. Contributing factors include modifications in effective treatment time, haemodynamic instability, and vascular access dysfunction. Fernández et al.[13] likewise reported that the main cause of suboptimal dialysis was lower than prescribed blood flow. Low dialysis dose measured by ionic dialysance has also been associated with reduced survival in patients with acute kidney failure [18].

Our analysis identified several quality-limiting factors directly involving nursing care: reduced effective dialysis time, definitive session termination, and staff shortages. Although limited literature addresses these factors in critically ill patients receiving IRRT, available studies highlight the essential role of nursing in early detection of intradialytic complications and timely intervention, ensuring both treatment quality and patient safety[20,29].

Vascular access emerged as a key preventable determinant of inadequate dialysis, with non-tunnelled venous catheters (NTVCs) exhibiting the highest complication rates[8,24]. In our study, 17.2% of sessions experienced NTVC dysfunction with high recirculation and line reversal, leading to frequent alarms and inability to achieve prescribed blood flow in 9.6% of cases. Similar findings were reported in a study from the Italian Hospital of Buenos Aires, where femoral NTVCs predominated and 22% of sessions required line reversal with suboptimal dialysis dose[25]. Although 36.3% of sessions were performed without heparin, this was not associated with increased circuit clotting, but rather with failure to achieve the prescribed blood flow. In critically ill patients, anticoagulation-free dialysis requires strict nursing surveillance to detect early signs of clotting risk (increased transmembrane pressure, reduced clearance) and prevent complete circuit coagulation. As blood flow does not appear to increase haemodynamic instability, maintaining an effective Qb≥250 mL/min is recommended to reduce clotting risk.

Dialyser selection also plays a significant role. Literature recommends optimizing dialyser performance using the smallest effective membrane surface, with appropriate blood flow and treatment duration[26]. In our study, high-flux membranes (FX 50–FX 60 Cordiax) were prescribed according to dialysis modality. Maduell et al. reported that smaller dialyser surface area reduces side effects and inflammatory response[30].

Achieving minimum Kt targets is recommended by clinical guidelines (KDIGO, European Renal Best Practice)[10,27]. We found no significant sex differences in achieving minimum Kt, consistent with prior studies[25]. However, factors independently associated with suboptimal Kt included catheter dysfunction, line reversal, reduction of SLED treatment time (>30 minutes), and definitive session termination, all of which limit solute clearance[31].

Although interruptions due to diagnostic procedures or monitor malfunction were not significantly associated with low Kt, their potential impact underscores the need to optimize treatment continuity and quality to ensure adequate clearance in critically ill patients receiving IHD/SLED[32].

This study is limited by its retrospective design and potential information loss, as well as temporal variation in clinical practice and technique adjustments. Furthermore, limited prior research exists evaluating the influence of nursing practice on dialysis quality in critically ill patients receiving IRRT.

In conclusion, dialysis quality in critically ill patients receiving IRRT depends on both non-modifiable factors (clinical status and reason for ICU admission) and modifiable factors, particularly early detection of vascular access dysfunction and timely intradialytic adjustments. These interventions improve tolerance, reduce complications, and prevent premature session termination.

The collaborative work of dialysis nurses, nephrologists, and ICU teams is fundamental to achieving an adequate dialysis dose with optimal haemodynamic tolerance.

Conflicts of interest

The authors declare no conflicts of interest related to this publication. This work reflects solely our academic and scientific findings.

The authors have no financial, commercial or personal relationships that could influence the results or interpretations presented.

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