Research Article

Investigation of the Effectiveness of Continuous Renal Replacement Therapy (Crrt) on Blood Urea Nitrogen and Serum Creatinine Values in Dogs and Cats with Renal Failure

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Doi : 10.5281/zenodo.23404206

Abstract

This study aimed to evaluate the effectiveness of continuous renal replacement therapy (CRRT) on blood urea nitrogen (BUN) and serum creatinine (CREA) levels in cats and dogs with renal failure where conventional treatment methods were insufficient. The distribution characteristics of the data were examined using the Shapiro-Wilk test, and it was determined that they did not show a normal distribution. Therefore, non-parametric statistical methods were applied. Comparisons between treatment groups (CRRT and medical treatment) were performed using the Kruskal-Wallis test, and pairwise post hoc comparisons were carried out using the Dunn test and Bonferroni correction for parameters showing significant differences. Changes over time in animals receiving CRRT treatment were examined using the Friedman test, and median values and time-dependent change curves were evaluated. Furthermore, the biochemical recovery time was analyzed using a Kaplan-Meier-like method. In cats, CRRT treatment resulted in a significant decrease in BUN, creatinine, and inorganic phosphorus levels; changes were more limited in the medical treatment group. In dogs, a decrease in parameters was also observed after CRRT, but some changes were not statistically significant. Kaplan-Meier analysis showed that biochemical recovery in cats occurred in approximately six hours for BUN and IP, and approximately five hours for creatinine. In dogs, creatinine recovered rapidly (approximately one hour), while BUN and IP returned to normal within six and four hours, respectively. CRRT offers a significant therapeutic advantage over conventional medical treatment in cases of severe renal failure, particularly in cats, by enabling faster and more significant recovery of important renal biomarkers.

Keywords: Renal Failure, CRRT, Blood Urea Nitrogen, Cat, Dog, Serum Creatinine, Continuous Renal Replacement Therapy

Introduction

Chronic kidney disease (CKD) is a significant health problem commonly seen in both cats and dogs, resulting from progressive kidney disease that typically develops over months or even years (Şahin and Çamkerten, 2003). The disease is characterized by irreversible and progressive impairment of nephron function, regardless of the initial cause. Although CKD is most commonly associated with older animals, it can also be observed in animals of different age groups. In acquired cases, the disease may stem from pathological processes occurring in

various structures of the kidney. These processes may affect the glomeruli, renal tubules, interstitial tissues, or the vascular structures supplying the kidney. However, in many clinical cases, it may not be possible to definitively determine the underlying cause of the disease (Börkü and Kurtdede et al., 2000).

Various diseases that may contribute to the development of CKD in pets have been identified. These include glomerulonephritis, bacterial pyelonephritis, diabetes mellitus, polycystic kidney disease, chronic urinary tract obstructions, nephrolithiasis, kidney damage caused by various nephrotoxic substances, and certain immune-mediated kidney diseases (Çelik and Bal, 2002). In particular, renal lymphoma is also considered a significant aetiological factor in cats. The damage occurring in the nephrons is permanent, and the loss of function is irreversible. This situation, over time, leads to the involvement of healthy nephrons as well and to a progressive deterioration in kidney function. The loss of nephrons triggers fibrotic processes in the renal tissue, and the areas containing damaged nephrons are gradually replaced by connective tissue. In cases where a significant proportion of nephrons is lost, renal atrophy, capsular adhesions, and structural changes may be observed. Furthermore, various pathological changes may develop during this process, including inflammation, fibrosis, hypertrophy, mineralization, tubular atrophy, glomerular sclerosis, mononuclear cell infiltration, and degeneration of the tubular epithelium (Altıntaş et al., 2006).

In the later stages of the disease, it is not only the kidney tissue that may be affected, but other organ systems as well. In particular, the rise in blood urea levels associated with chronic kidney failure can lead to the development of degenerative changes in the gastrointestinal system. These pathological changes are most commonly observed in the stomach and intestinal tissues (Börkü et al., 2000).

The diagnosis of chronic kidney disease requires a combined assessment of clinical evaluations and laboratory findings. In addition to hematological and biochemical analyses, the diagnostic process also utilizes electrocardiographic, radiographic, ultrasonographic, and pathological examinations. Among the hematological findings, increases in white blood cell count, reticulocyte count, and mean corpuscular volume (MCV) are frequently observed, while decreases in red blood cell count and hematocrit are noteworthy. In serum biochemical analyses, significant increases in urea, creatinine, phosphorus, and potassium levels may be detected. Urinalysis may reveal findings such as decreased urine specific gravity, haematuria, and albuminuria. Sediment examinations may identify epithelial cells, crystals, various cellular structures, and filamentous formations. Furthermore, microbiological examination of urine samples has isolated various bacterial pathogens, including Staphylococcus spp., Streptococcus spp., Proteus mirabilis, Klebsiella pneumoniae, and Pseudomonas aeruginosa (Börkü et al., 2000).

The development of extracorporeal blood purification methods dates back to the early 20th century. Experiments conducted by a pharmacologist at the Johns Hopkins University School of Medicine laid the foundations for the dialysis techniques used today. In these experiments, arterial blood taken from animals was mixed with an anticoagulant, passed through a system consisting of semi-permeable membranes, and then returned to the circulation. This system comprised semi-permeable membranes formed by pipette-like tubes situated within a liquid medium. The researchers demonstrated that the chemical properties of the blood could be altered by changing the composition of the surrounding fluid. This method, defined as ‘live diffusion’ or ‘live dialysis’, is based on the principle of diffusion and forms the basis for subsequent intermittent hemodialysis (IHD) applications (Acierno, 2011).

Continuous renal replacement therapy (CRRT), on the other hand, is a more recently developed method of extracorporeal blood purification. As the name suggests, this method is administered continuously

and continues until kidney function improves or the patient switches to intermittent dialysis treatment. In CRRT, as in intermittent hemodialysis, the patient's blood is passed through a dialyzer composed of semi-permeable membrane fibers. However, unlike intermittent hemodialysis, in CRRT the removal of solutes is achieved not only by diffusion but also through convection and, to a more limited extent, adsorption mechanisms (Bayendur and Acar, 2024)

One of the key advantages of CRRT is that, thanks to the slow and continuous administration of treatment, electrolyte balance and acid-base balance can be controlled more stable. The principle of continuous operation ensures that the treatment has an effect closer to that of physiological kidney function. Furthermore, thanks to the convection mechanism, it is possible to remove larger molecules from the blood that are difficult to eliminate by diffusion alone. These molecules are closer in size to the substances filtered by healthy kidneys. In contrast, intermittent hemodialysis aims to rapidly alter uremic toxins, fluid balance, and acid-base status within a short period. Consequently, the procedure requires the production of large volumes of pure dialysate, which necessitates complex infrastructure equipped with specialised water purification systems (Özkalıpcı, 2025).

In CRRT, however, the combined diffusion and convection mechanisms allow the use of pre-prepared sterile replacement fluids. This reduces the need for complex water purification systems and significantly simplifies maintenance requirements between treatments (Acierno, 2011).

Cases of renal failure, which are frequently encountered at veterinary clinics, animal hospitals and practices in Turkey, generally require complex management and long-term treatment protocols, regardless of whether they present as acute or chronic. During this process, elevated blood urea nitrogen and serum creatinine levels lead to various clinical symptoms due to difficulty controlling them; this results in progressive deterioration of the patient's general condition and, in advanced stages, irreversible tissue damage. Disruption of osmotic balance due to nephron loss may lead to various cardiovascular complications (Börkü et al., 2000).

Imbalances in electrolyte levels lead to systemic effects. The aim is to reduce blood urea nitrogen (BUN) and creatinine levels—which are used for diagnosis and monitoring in renal failure—as quickly as possible without causing permanent loss of nephrons in the renal tissue (Şentürk et al., 2003).

In this study, however, the aim was to comparatively evaluate the changes in high BUN and creatinine levels—which cannot be sufficiently reduced by methods such as parenteral fluid therapy—following continuous renal replacement therapy (Kang et al., 2024).

Material and Method

Animal Material

This study was conducted in accordance with Decision No. 32 of 15 November 2023 issued by the Local Ethics Committee for Animal Experiments at Kırıkkale University.

The patient material for this study consisted of a minimum of 10 cats and 10 dogs brought to the Research and Application Hospital of the Faculty of Veterinary Medicine at Kırıkkale University; these were animals in which a diagnosis of renal failure had been established following an assessment of biochemical parameters in relation to their symptoms.

Following investigations that included a complete blood count, blood biochemical parameters, and blood gas measurements, radiographic and ultrasonographic examinations were performed; diagnoses were made based on these findings, and patients were identified for whom CRRT was indicated**.**

Laboratory Tests

Diagnosis of Renal Failure

Patients included in the study, regardless of age, were assessed based on clinical examination findings, particularly those with a history of loss of appetite, fatigue, vomiting, bad breath, reduced urine output, and sudden deterioration in general condition. Patients presenting with these symptoms were screened using a CBC (complete blood count) to assess for suspected conditions such as vomiting, reduced urine output, dehydration, hypovolaemia–hypervolemia, and hypothermia–hyperthermia; at this stage, HCT, WBC, RBC, HGB, and MCHC values were considered. In patients suspected of having renal failure, biochemical parameters such as BUN, CREA, IP, and Na-K-Cl were first examined from the samples taken to assess renal function. Based on these parameters, radiography and ultrasonography were performed for differential diagnosis.

Prior to continuous renal replacement therapy, the cats' CBC, biochemical parameters and blood gas measurements were recorded. During treatment, BUN, CREA, IP, K and blood gas measurements were taken at the start, 1 hour, 2 hours, 4 hours, 6 hours, 8 hours, 10 hours and 12 hours, depending on the progress of the treatment and the patient's condition**.**

Hematological Analyses

To perform hematological analyses on the cats and dogs in the study group, 1 ml of blood was collected into EDTA-containing tubes and 3 ml into anticoagulant-free tubes from the cephalic vein of the forearm. To obtain serum samples, the blood collected in anticoagulant-free tubes was centrifuged immediately at 3000 rpm for 10 minutes. The separated serum samples were transferred to Eppendorf tubes and stored at -20°C. Blood samples collected in EDTA tubes were analyzed using a hematology analyzer (Mindray®, VH5R) to perform a complete blood count. The results were recorded.

Blood samples collected in tubes without anticoagulant (FUJI DRI-CHEM NX500IC) were analyzed using a biochemistry analyzer to measure biochemical parameters. The results were recorded. Blood gas measurements were performed using a blood sample syringe containing dry heparin (EDAN I15VET device). The results were recorded.

Continuous Renal Replacement Therapy

Prior to the procedure, an intravenous catheter was inserted into the cephalic vein of the forearm. This was followed by intravenous sedation. An intratracheal tube was inserted to prepare for gas anaesthesia. Isoflurane was selected as the anaesthetic gas.

Prior to the procedure, bidirectional catheterisation of the jugular vein was performed in cats and dogs. The BAXTER PRISMAFLEX device was used for this procedure.

Statistical Analyses

SPSS 10.0 was used to analyze numerical data for variables identified in cats and dogs. The arithmetic mean (X) and standard deviation (SX) of the parameters were calculated. Differences at a significance level of $P \leq 0.05$ were considered statistically significant.

The distribution characteristics of the data obtained in the study were assessed using the Shapiro–Wilk normality test. The analysis revealed that the data did not follow a normal distribution; consequently, non-parametric statistical methods were employed. The Kruskal–Wallis test was applied to compare biochemical parameters between the different treatment groups (CRRT, medical treatment and healthy control). Following the Kruskal–Wallis analysis, which detected statistically significant differences among the parameters, the Dunn multiple comparison test was used to perform pairwise comparisons between groups; a Bonferroni correction was applied to reduce the likelihood of Type I errors from multiple comparisons. The Friedman test, a non-parametric method suitable for repeated measurements, was used to evaluate changes in biochemical parameters over time in animals receiving CRRT. To assess treatment efficacy, the difference between the baseline value before treatment and the post-treatment value was calculated for each individual, and this change was expressed as the Δ (delta) value. The Δ value was calculated using the following formula:

$$\Delta = \text{Value_final} - \text{Value_initial}$$

A Kaplan-Meier-like analytical approach was used to assess the duration of biochemical recovery following CRRT treatment. In this analysis, recovery was defined as a reduction of at least 50% in the relevant biochemical parameter compared with its baseline value. Using this approach, the time interval during which the effect of CRRT treatment on biochemical parameters began to emerge was assessed. All data obtained in the study are presented as the median (IQR: interquartile range). Statistical analyses were performed using R Studio (Version 4.3.3), and a p-value of <0.05 was considered statistically significant.

Results

The distribution of pre-treatment biochemical parameters in the cats and dogs included in the study was assessed, and the initial values between the groups were examined (Table 1).

Table 1. Distribution of Initial Biochemical Parameters

Species	Parameter	Group	Median	Q1	Q3
Cat	BUN	CRRT	140	130	140
		Medical	57	36	72
	CRE	CRRT	10,21	7,00	12,65
		Medical	2,52	1,96	4,63
	IP	CRRT	11,60	10,20	15,00
		Medical	5,00	4,30	7,10
Dog	BUN	CRRT	122	103	140
	CRE	CRRT	9,40	8,03	10,58
	IP	CRRT	11,20	10,05	14,50

The study assessed whether there was a statistically significant difference in the distribution of biochemical parameters between different treatment groups in cats and dogs (Table 2).

Table 2. Results of the Kruskal-Wallis Test

Species	Parameter	H	p
Cat	BUN	10.65	0.001
Cat	CRE	10.40	0.001
Cat	IP	6.81	0.009
Dog	BUN	0.56	0.450
Dog	CRE	2.53	0.110
Dog	IP	1.72	0.180

Statistically significant differences were found between the groups in cats with regard to BUN, creatinine (CRE) and inorganic phosphorus (IP) levels ($p<0.05$). In contrast, no statistically significant differences were found between the groups in dogs for the biochemical parameters assessed ($p>0.05$). These results demonstrate that renal function indicators, particularly in cats, differ markedly between the treatment groups. The results of the multiple-comparison analyses, conducted to determine which treatment groups were responsible for the differences between groups, are presented in Table 3.

Table 3. Results of pairwise comparisons between groups regarding biochemical parameters in cats

Species	Parameter	Comparison	p*
Cat	BUN	CRRT vs Medical	0,004
Cat	CRE	CRRT vs Medical	0,004
Cat	IP	CRRT vs Medical	0,031

Statistically significant differences were found between the CRRT and medical treatment groups in cats in terms of BUN, creatinine (CRE) and inorganic phosphorus (IP) levels ($p<0.05$). The results obtained indicate that the levels of these biochemical parameters differ between cases receiving CRRT and those receiving medical treatment.

The changes in biochemical parameters over time in cats and dogs receiving CRRT are shown in Table 4, whilst the time-dependent change curves for these biochemical parameters are shown in Figure 1.

Table 4. Results on the Time-Dependent Changes in Biochemical Parameters During CRRT Treatment

Species	Parameter	χ^2	p
Cat	BUN	28,63	<0,001
	CRE	29,66	<0,001
	IP	24,00	<0,001
Dog	BUN	10,17	0,11
	CRE	11,03	0,08
	IP	11,95	0,06

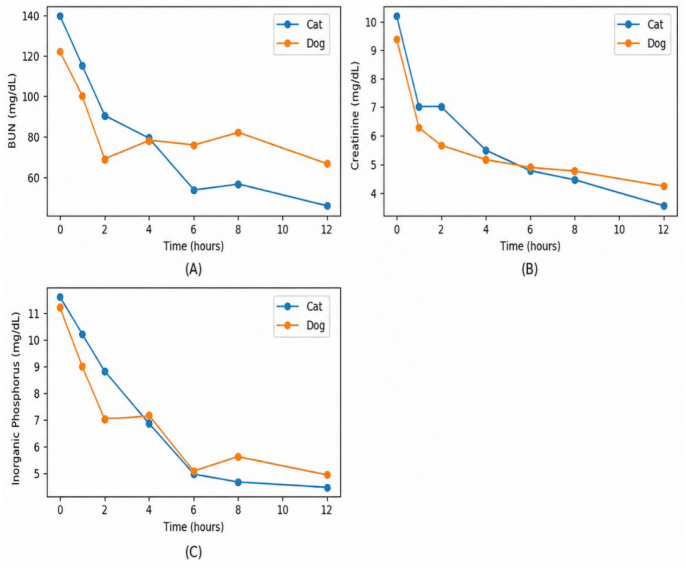


Figure 1. Time-dependent changes in biochemical parameters during CRRT treatment.
(A) The time-dependent changes in BUN levels, (B) the time-dependent changes in creatinine levels and (C) the time-dependent changes in inorganic phosphorus levels are shown for cats and dogs.

It was found that BUN, creatinine (CRE) and inorganic phosphorus (IP) levels in cats undergoing CRRT showed statistically significant changes over time ($p<0.001$). In dogs, however, the changes observed over time in BUN, creatinine and phosphorus levels were not statistically significant ($p > 0.05$). Nevertheless, it is noteworthy that p-values for some parameters in dogs were close to the threshold for statistical significance. These findings indicate that biochemical changes associated with CRRT treatment are more pronounced in cats in particular.

The changes (Δ) in biochemical parameters between pre-treatment and post-treatment levels for the treatments examined in the study were evaluated, and the results are presented in Table 5 and Figures 2 and 3.

Table 5. Changes Before and After Treatment (Median)

Species	Parameter	CRRT Δ	Medical Δ	p	Effect size (r)
Cat	BUN	-76	+15	0.004	0.72
	CRE	-5.4	+0.7	0.004	0.70
	IP	-7.2	-0.1	0.031	0.48
Dog	BUN	-48	—	0.450	0.12
	CRE	-3.1	—	0.110	0.19
	IP	-3.9	—	0.180	0.15

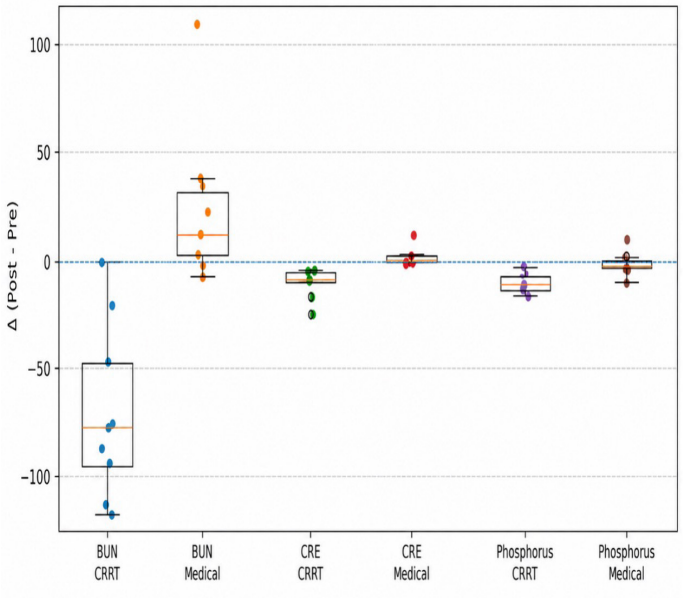


Figure 2. Changes in Biochemical Parameters in Cats Undergoing CRRT and Medical Treatment

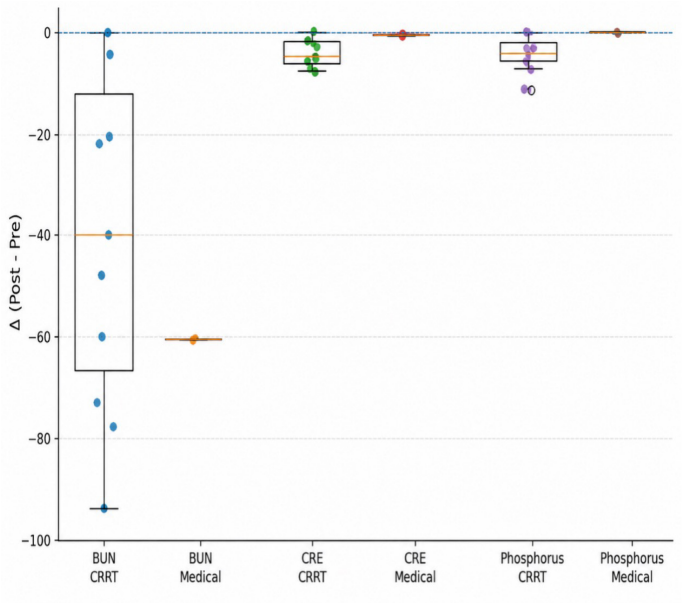


Figure 3. Changes in Biochemical Parameters in Dogs Undergoing CRRT and Medical Treatment

A marked reduction in BUN, creatinine (CRE), and inorganic phosphorus (IP) levels was observed in the group of cats receiving CRRT. Whilst a median reduction of 76 mg/dL in BUN levels was observed in cats receiving CRRT, an increase in this parameter was noted in the medical treatment group. Similarly, a median decrease of 5.4 mg/dL in creatinine levels was observed in the CRRT group, whilst a slight increase was noted in the medical treatment group. A median decrease of 7.2 mg/dL in inorganic phosphorus levels was also observed in the CRRT group. The results of the statistical analysis indicate that these differences are significant. It was determined that the differences between the CRRT and medical treatment groups in the BUN and creatinine parameters were statistically significant ($p=0.004$ and $p=0.004$, respectively) and had a high effect size (Cohen's $r=0.72$ and Cohen's $r=0.70$). A statistically significant difference was also observed between the groups in inorganic phosphorus levels ($p = 0.031$), with a moderate effect size (Cohen's $r = 0.48$).

A downward trend in biochemical parameters was also observed in dogs following CRRT treatment. In dogs, a median decrease of 48 mg/dL in BUN levels, a reduction of 3.1 mg/dL in creatinine levels and a decrease of 3.9 mg/dL in inorganic phosphorus levels were observed. However, it was found that these changes observed in dogs were not statistically significant ($p > 0.05$). When effect sizes were examined, it was seen that the effect on biochemical parameters in dogs was of a low magnitude (Cohen's $r = 0.12–0.19$).

When these findings are considered together, it is

evident that CRRT treatment is effective in reducing biochemical parameters in cases of renal failure; however, this effect is particularly more prominent and pronounced in cats.

The duration of the improvement in biochemical parameters observed in animals undergoing CRRT treatment was assessed, and the results are presented in Table 6.

Table 6. Median Duration of Biochemical Recovery Following CRRT Treatment

Species	BUN	CRE	IP
Cat	6 hours	5 hours	6 hours
Dog	6 hours	1 hour	4 hours

In cats undergoing CRRT, the median time for a 50% reduction in biochemical parameters compared with baseline values was found to be approximately 6 hours for BUN and IP, and approximately 5 hours for creatinine. In dogs, however, an earlier improvement in creatinine levels was observed, with the median time to improvement determined to be 1 hour. For BUN and IP parameters, the median times to improvement were calculated as 6 hours and 4 hours, respectively. These findings demonstrate that CRRT treatment has a marked effect on biochemical parameters within a short period of time.

To evaluate the temporal aspect of the effect of CRRT treatment on biochemical parameters, biochemical recovery times were analysed using the Kaplan-Meier approach. In this analysis, recovery was defined as a reduction of at least 50 per cent in the relevant biochemical parameter compared to its baseline value. The median recovery times and confidence intervals obtained from the analysis are presented in Table 7.

Table 7. Time to Biochemical Recovery Following CRRT Treatment (Kaplan-Meier Analysis)

Species	Parameter	Recovery time (hours)	%95 CI	Recovered animal (n)
Cat	BUN	6	4-8	9
	CRE	5	4-6	9
	IP	6	4-8	9
Dog	BUN	6	4-8	6
	CRE	1	1-2	6
	IP	4	3-6	6

According to the results of the Kaplan-Meier analysis, the median time to biochemical recovery for BUN and IP parameters in cats receiving CRRT was 6 hours, whilst for creatinine it was 5 hours. An examination of the Kaplan-Meier curves reveals that improvement in the biochemical parameters became particularly evident within the first 6 hours of treatment (Figure 4).

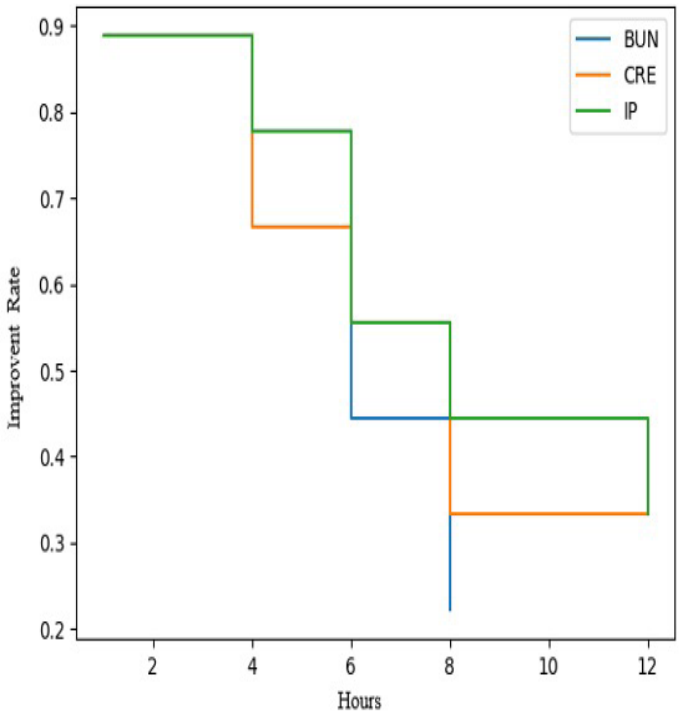


Figure 4. Changes in Biochemical Parameters Over Time in Cats During CRRT Treatment

On examination of the figure, a marked trend towards improvement in biochemical parameters over time is observed in cats receiving CRRT treatment. In particular, a downward trend in BUN, creatinine (CRE) and inorganic phosphorus (IP) levels becomes apparent from the very first hours of treatment. When the recovery curves shown in the graph are evaluated, a faster trend of improvement is observed, particularly in IP levels, during the early stages of treatment. The rapid decline observed in the IP parameter during the first few hours suggests that inorganic phosphorus responds more quickly to CRRT treatment than the other biochemical parameters. As for creatinine levels, improvement becomes apparent in the middle hours. In contrast, the decline in BUN levels is more gradual, and improvement becomes apparent in the later hours. Overall, it is evident that CRRT treatment has a rapid effect on biochemical parameters in cats and leads to marked biochemical improvement, particularly within the first 6–8 hours. This finding demonstrates that CRRT is an effective method for removing metabolic waste products in cats with acute kidney injury.

According to the Kaplan-Meier analysis, the median time to biochemical recovery for the creatinine (CRE) parameter was 1 hour in dogs receiving CRRT. In contrast, the median time to recovery was calculated as 6 hours for the BUN parameter and 4 hours for the inorganic phosphorus (IP) parameter. An examination of the Kaplan-Meier curves reveals that biochemical improvement in creatinine levels occurred more rapidly in the early stages of treatment, whilst improvement in the BUN and IP parameters followed a more gradual course (Figure 5).

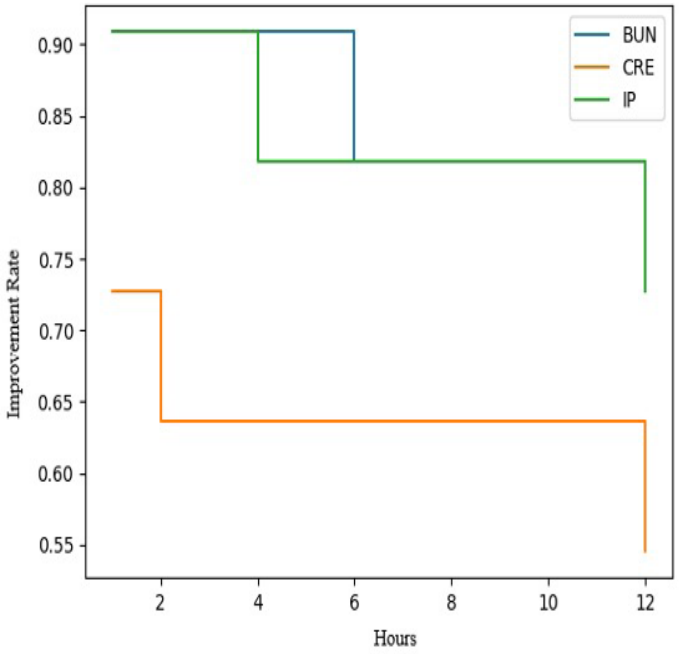


Figure 5. Changes in Biochemical Parameters Over Time in Dogs During CRRT Treatment

It has been observed that biochemical parameters in dogs tend to return to normal levels over time following CRRT treatment. However, it is noteworthy that this recovery follows a more gradual course compared to the changes observed in cats. An analysis of the curves in the graph reveals that inorganic phosphorus (IP) levels remain relatively stable during the early stages of treatment, and the rate of recovery is largely maintained. As for BUN levels, a gradual change in the rate of recovery is observed after the first few hours. In terms of creatinine (CRE) values, it is noteworthy that the change was more limited throughout the treatment period, and the rate of improvement remained lower than for the other parameters. Overall, it appears that CRRT treatment has a positive effect on biochemical parameters in dogs; however, this effect manifests more slowly and to a lesser extent than in cats. This suggests that CRRT treatment may elicit different biochemical responses between species.

When the findings of the study were evaluated overall, it was determined that there were significant differences between the CRRT and medical treatment groups in terms of baseline biochemical parameters. It was observed that BUN, creatinine and inorganic phosphorus levels were higher in cats receiving CRRT compared with the medical treatment group. In contrast, no statistically significant differences were detected between the groups in dogs with respect to baseline biochemical parameters. When changes in biochemical parameters over time were examined in animals receiving CRRT, BUN, creatinine, and inorganic phosphorus levels decreased significantly in cats during treatment. In dogs, whilst a time-dependent downward trend was observed in the same parameters, these changes were not statistically significant. An analysis of the changes between pre- and post-treatment values showed that a marked decrease in BUN, creatinine, and inorganic phosphorus levels occurred in the group of cats receiving CRRT. In the group receiving medical treatment, however, more limited changes in biochemical parameters were observed. In dogs, a downward trend in biochemical parameters was also observed following CRRT treatment. An evaluation using the Kaplan-Meier method revealed that biochemical recovery occurred within approximately 6 hours for BUN and inorganic phosphorus (IP) parameters, and within approximately 5 hours for creatinine in cats. In dogs, however, an earlier biochemical improvement in creatinine levels was observed, with a median time to improvement of approximately 1 hour. For the BUN and IP parameters, the times to recovery were approximately 6 and 4 hours, respectively.

Discussion

This study aimed to evaluate the effects of continuous renal replacement therapy (CRRT) on BUN, creatinine, and inorganic phosphorus levels in cats and dogs with chronic kidney failure. The findings obtained in this context are as follows:

An assessment of pre-treatment biochemical parameters in the cats and dogs included in the study revealed significant differences in baseline levels between the CRRT and medical treatment groups. In the group of cats receiving CRRT, the median BUN was 140 mg/dL (Q1: 130, Q3: 140), the median creatinine (CRE) was 10.21 mg/dL (Q1: 7.00, Q3: 12.65) and the median inorganic phosphorus (IP) level was 11.60 mg/dL (Q1: 10.20, Q3: 15.00). In the medical treatment group, the median BUN was 57 mg/dL (Q1: 36, Q3: 72), the median creatinine was 2.52 mg/dL (Q1: 1.96, Q3: 4.63) and IP 5.00 mg/dL (Q1: 4.30, Q3: 7.10). These results suggest that the cats in the CRRT group had a more advanced degree of renal dysfunction compared with those receiving

medical treatment. In dogs, however, only the baseline biochemical values of cases included in the CRRT group were assessed, and the median BUN was 122 mg/dL (Q1: 103, Q3: 140), creatinine 9.40 mg/dL (Q1: 8.03, Q3: 10.58) and IP 11.20 mg/dL (Q1: 10.05, Q3: 14.50). These values demonstrate that elevated biochemical parameters were also observed in dogs prior to treatment. These findings are consistent with the mean urea levels of 450 ± 25 mg/dL and creatinine levels of 5.9 ± 2 mg/dL reported by Börkü et al. (2000) in cats, and the mean urea levels of 370 ± 12 mg/dL and creatinine levels of 6.2 ± 3 mg/dL reported in dogs. It has been stated that, in chronic kidney disease, nitrogenous metabolic waste products such as urea and creatinine accumulate in the blood due to the progressive decline in kidney function, leading to the development of azotaemia and uraemia (Grollman & Grollman, 1959; Squires, 1996). It has been reported that these biochemical changes are closely related to the clinical severity of the disease and may be accompanied by systemic symptoms such as vomiting, loss of appetite, weight loss and lethargy (English, 1973; Squires, 1996). In clinico-pathological studies conducted on cats, findings such as azotaemia, hyperphosphataemia, metabolic acidosis and non-regenerative anaemia have been commonly observed, and it has been emphasised that these parameters are important indicators in the assessment of the disease (DiBartola et al., 1987). In our study, the high baseline BUN, creatinine and inorganic phosphorus levels observed in cats undergoing CRRT support the conclusion that these cases had a more advanced degree of renal dysfunction. Previous studies have found azotemia to be common in cats with chronic kidney disease, with a high prevalence reported, particularly in native short-haired cats of stray origin (King et al., 2007). These findings are consistent with the elevated BUN and creatinine levels in animals with azotemia reported by Geist et al. (2011), Elliott (2010), Jepson et al. (2009), and Chew et al. (2005). Furthermore, elevated serum phosphorus levels have been identified as an early indicator of azotemia by Jepson et al. (2009) and Squires (2007), whilst Little et al. (2007) reported that hyperphosphataemia is frequently observed in cats with urinary tract obstruction. In this context, the high baseline values observed in cats and dogs in the CRRT group are consistent with the literature and reflect the degree of renal dysfunction prior to treatment.

These findings are consistent with the results from CRRT in six dogs, as reported by Han et al. (2015). In that study, high BUN levels prior to the start of treatment (in some cases >150 mg/dL) were gradually reduced with CRRT, and a marked decrease in pre-BUN values was observed over the first five sessions. Treatment efficacy, as assessed by the urea reduction ratio (URR), was reflected in good clinical outcomes, particularly in dogs with an URR range of 57–72%; however, one case with severe azotaemia and electrolyte imbalance was lost after the third session. This finding demonstrates that an early response to treatment is important in predicting clinical outcomes and that CRRT safely supports renal function through gradual urea clearance. These high baseline values indicate the presence of marked azotaemia prior to CRRT and are consistent with the median BUN and creatinine values reported by Chen, Klainbart, Kelmer and Segev (2023) in dogs with acute kidney injury prior to CRRT. Chen et al. (2023) reported that CRRT is a safe and effective treatment, with urea levels decreasing gradually over time and renal function improving in a controlled manner. The study also emphasized that treatment efficacy can be optimized and complications minimized through appropriate dose management and control of the hourly urea reduction rate (URR). Furthermore, the complications reported in that study (filter occlusion, electrolyte and acid-base imbalances) were consistent with the limited hemodynamic and anticoagulation-related complications observed in our study. In this context, CRRT contributes to the rapid and safe improvement of biochemical parameters in cases of severe renal failure in both cats and dogs.

The study investigated the distribution of biochemical parameters in cats and dogs across different treatment groups. In cats, statistically significant differences were observed between the groups in terms of BUN ($H=10.65$; $p=0.001$), creatinine (CRE) ($H=10.40$; $p=0.001$) and inorganic phosphorus (IP) ($H=6.81$; $p=0.009$) levels; this finding is consistent with studies in the literature reporting increased BUN and creatinine levels in cats with azotaemia (Geist et al., 2011; Elliott, 2010; Jepson et al., 2009; Chew et al., 2005). Similarly, it has been reported that serum phosphorus levels rise in cats developing azotaemia and that hyperphosphataemia is frequently observed, particularly in cases of postrenal azotaemia (Jepson, 2009; Squires, 2007; Little, 2007). In dogs, however, no significant differences were observed between groups in BUN ($H=0.56$; $p=0.450$), creatinine ($H=2.53$; $p=0.110$) and IP ($H=1.72$; $p=0.180$) levels; this finding supports studies suggesting that baseline biochemical values in dogs may be more variable depending on the severity of azotaemia (Malouin et al., 2007; Drobatz et al., 2008). The increase in BUN and creatinine, hyperphosphataemia and changes in

biochemical parameters in cats with azotaemia are consistent with previous studies indicating that these vary depending on the type of azotaemia (Squires, 2007; Little, 2007; Jepson, 2009; Geist et al., 2011; Elliott, 2010; Chew et al., 2005). Furthermore, proteinuria is associated with azotaemia, and the urine protein-to-creatinine ratio has been reported as an important parameter in the assessment of biochemical changes (Lees, 2005; Grauer, 2011). The absence of intergroup differences in dogs suggests that the effect of kidney disease on biochemical parameters may be less pronounced compared to cats, or that baseline values may have limited statistical power (Malouin et al., 2007; Drobatz et al., 2008). These findings support the report by Börkü et al. (2000) that elevated urea and creatinine levels are associated with clinical signs (vomiting, dehydration, weakness, changes in urination).

In chronic renal failure, a reduction in glomerular filtration rate leads to the accumulation of nitrogenous metabolic waste products such as urea and creatinine in the blood, resulting in azotaemia and the development of the uraemic syndrome; these biochemical changes are associated with the clinical severity of the disease, and in advanced cases, metabolic disorders and systemic clinical symptoms may arise (English, 1973; Grollman & Grollman, 1959).

In our study, the elevated BUN, creatinine and IP values observed across the treatment groups in cats suggest that, in some cases, renal function loss is at an advanced stage.

A multiple comparison analysis of biochemical parameters between the CRRT and medical treatment groups in cats revealed statistically significant differences in BUN, creatinine (CRE) and inorganic phosphorus (IP) levels (BUN: $p=0.004$; CRE: $p=0.004$; IP: $p=0.031$). These results indicate that, in cats undergoing CRRT, baseline BUN, creatinine and IP values were higher compared to those in cats receiving medical treatment. In dogs, however, no pairwise comparisons between groups could be performed, and no statistically significant differences were found in terms of baseline parameters ($p>0.05$); this finding supports the notion that baseline biochemical values in dogs may be more variable depending on the severity of azotaemia, and that no marked differences may arise between groups prior to treatment (Malouin et al., 2007; Drobatz et al., 2008). The literature reports that conditions such as heart failure, acute and chronic renal failure, urinary tract obstructions, diabetes mellitus and dehydration in cats lead to increased BUN and creatinine levels (Malouin et al., 2007; Syme et al., 2006; Drobatz et al., 2008). Similarly, BUN and creatinine levels are elevated in cats with kidney disease and are associated with clinical signs (King et al., 2007; Boyd et al., 2008). It has been noted in the literature that phosphorus levels rise in cases of postrenal azotaemia and urinary tract obstruction (Jepson et al., 2009; Elliott, 2010; Little, 2007), and the high IP values observed in the CRRT group in our study are consistent with these findings. Furthermore, it has been reported that anemia is common in animals with chronic kidney disease (CKD) and that this develops as a result of reduced erythropoietin production (Cowgill, 1992). Uremia can lead to complications such as inflammation, edema, and ulceration of the gastrointestinal tract; this condition may manifest as clinical signs such as anorexia, vomiting, and diarrhea (Krawiec, 1996). It has also been emphasized that CKD is prevalent in older cats and dogs, and that abnormalities in biochemical parameters reflect the severity of the disease (Rubin, 1997). Clinical studies have reported that findings such as vomiting, anemia, a dull coat, and changes in urine are associated with elevated biochemical parameters; these findings support the contribution of CRRT treatment to biochemical and clinical improvement (Börkü et al., 2000).

When the time-dependent changes in biochemical parameters were evaluated in cats and dogs undergoing CRRT treatment, statistically significant decreases were observed in cats for BUN ($\chi^2=28.63$; $p<0.001$), creatinine (CRE) ($\chi^2=29.66$; $p<0.001$), and inorganic phosphorus (IP) ($\chi^2=24.00$; $p<0.001$) were observed in cats throughout the treatment period. These findings indicate that CRRT treatment leads to a marked improvement in biochemical parameters in cats and may contribute to clinical recovery. In dogs, however, changes in BUN ($\chi^2=10.17$; $p=0.11$), creatinine ($\chi^2=11.03$; $p=0.08$) and IP ($\chi^2=11.95$; $p=0.06$) were not found to be statistically significant; however, the fact that the p-values for some parameters were close to the threshold of significance suggests that CRRT may also have a gradual effect in dogs. Various studies in the literature have reported elevated levels of BUN, creatinine and phosphorus in cats with chronic and postrenal azotaemia (Geist et al., 2011; Elliott, 2010; Jepson et al., 2009; Chew et al., 2005; Malouin et al., 2007; Syme et al., 2006; Drobatz et al., 2008; King et al., 2007; Boyd et al., 2008; Little, 2007), and the elevated biochemical values observed in our study prior to CRRT are consistent with these findings. Furthermore, the literature reports that hyperkalaemia and electrolyte imbalances are common in cats with azotaemia and that, in some cases, these lead to ECG changes (Squires, 2007; Malouin et al., 2007; Greco

et al., 2007; Chew, 2011); in our study, hyperkalemia was also detected in cats with postrenal azotaemia, and certain electrocardiographic changes were observed. Changes in urine specific gravity and proteinuria in cats with azotaemia have been documented in the literature, and these parameters vary depending on the type of azotaemia (Lees, 2005; Grauer, 2011; Jepson, 2009; Little, 2007); in our study, the decrease in urine specific gravity in cats diagnosed with chronic kidney disease and the markedly elevated urine protein-to-creatinine ratio in cats with postrenal azotaemia are consistent with the literature. The significant decreases in BUN, creatinine and phosphorus levels observed during the course of treatment following CRRT have not yet been sufficiently reported in the literature; this can be regarded as an original contribution of our study and demonstrates that CRRT treatment provides rapid and effective biochemical recovery in cats. The fact that the changes observed in dogs were not statistically significant has been interpreted as a finding that requires support from a larger number of cases and long-term follow-up.

When the time-dependent changes in biochemical parameters were evaluated in cats and dogs undergoing CRRT treatment, statistically significant decreases were observed in cats for BUN (χ^2=28.63; p<0.001), creatinine (CRE) (χ^2=29.66; p<0.001) and inorganic phosphorus (IP) (χ^2=24.00; p<0.001) were observed in cats throughout the treatment period. These findings indicate that CRRT treatment leads to a marked improvement in biochemical parameters in cats and may contribute to clinical recovery. In dogs, however, changes in BUN (χ^2=10.17; p=0.11), creatinine (χ^2=11.03; p=0.08) and IP (χ^2=11.95; p=0.06) were not found to be statistically significant; however, the fact that the p-values for some parameters were close to the threshold of significance suggests that CRRT may also have a gradual effect in dogs. Various studies in the literature have reported elevated levels of BUN, creatinine and phosphorus in cats with chronic and postrenal azotaemia (Geist et al., 2011; Elliott, 2010; Jepson et al., 2009; Chew et al., 2005; Malouin et al., 2007; Syme et al., 2006; Drobatz et al., 2008; King et al., 2007; Boyd et al., 2008; Little, 2007), and the elevated biochemical values observed in our study prior to CRRT are consistent with these findings. Furthermore, the literature reports that hyperkalaemia and electrolyte imbalances are common in cats with azotaemia and that, in some cases, these lead to ECG changes (Squires, 2007; Malouin et al., 2007; Greco et al., 2007; Chew, 2011); in our study, hyperkalaemia was also detected in cats with postrenal azotaemia, and certain electrocardiographic changes were observed. Changes in urine specific gravity and proteinuria in cats with azotaemia have been documented in the literature, and these parameters vary depending on the type of azotaemia (Lees, 2005; Grauer, 2011; Jepson, 2009; Little, 2007); in our study, the decrease in urine specific gravity in cats diagnosed with chronic kidney disease and the markedly elevated urine protein-to-creatinine ratio in cats with postrenal azotaemia are consistent with the literature. The significant decreases in BUN, creatinine, and phosphorus levels observed during treatment following CRRT have not yet been adequately reported in the literature; this constitutes an original contribution of our study and demonstrates that CRRT provides rapid and effective biochemical recovery in cats. The fact that the changes observed in dogs were not statistically significant has been interpreted as a finding that requires support from a larger number of cases and long-term follow-up.

The effect of CRRT treatment on biochemical parameters in cats and dogs was assessed based on pre- and post-treatment change (Δ) values. In the group of cats receiving CRRT, the median BUN value decreased by 76 mg/dL, whilst a 15 mg/dL increase was observed in the medical treatment group (p=0.004; Cohen's r=0.72). Creatinine (CRE) levels showed a median decrease of 5.4 mg/dL in the CRRT group, whilst a slight increase of 0.7 mg/dL was observed in the medical treatment group (p=0.004; Cohen's r=0.70). A median decrease of 7.2 mg/dL in inorganic phosphorus (IP) levels was also observed in the CRRT group, whilst there was virtually no change in the medical treatment group (-0.1 mg/dL) (p=0.031; Cohen's r=0.48). A downward trend in BUN, creatinine and IP levels following CRRT was observed in dogs; however, this was not found to be statistically significant, and the effect sizes were calculated as 0.12, 0.19 and 0.15, respectively (p>0.05). These results are consistent with studies by Geist et al. (2011), Elliott (2010), Jepson et al. (2009), Chew et al. (2005), Squires (2007), and Little et al. (2007), which reported elevated BUN, creatinine, and phosphorus levels in cats with chronic and postrenal azotemia. It has been reported that hyperphosphatemia may worsen renal function and that a decrease in glomerular filtration rate may trigger the uremic syndrome (Zager, 1982; English, 1973; Rubin, 1997). The beneficial effect of a mineral-restricted diet on biochemical parameters and the pathophysiology of anemia-related abnormalities has also been highlighted in the literature. (Brown, O'Brien and Osborne, 1991; Cowgill, 1992). It has been noted in the literature that hyperkalaemia and electrolyte imbalances are common in cats with azotaemia and

may lead to ECG changes in some cases; in our study, hyperkalaemia was detected in cats with post-renal azotaemia and electrocardiographic changes were observed (Squires, 2007; Malouin et al., 2007; Di Bartola et al., 2006; Greco et al., 2007; Chew, 2011). Furthermore, it has been reported that urine specific gravity and the protein-to-creatinine ratio may vary depending on the type of azotaemia (Lees, 2005; Grauer, 2011; Jepson, 2009; Little, 2007); the low urine specific gravity and high protein-to-creatinine ratio observed in our study are consistent with the literature. A median decrease of 7.2 mg/dL in phosphorus in cats following CRRT supports findings in the literature that elevated phosphorus levels may be reversible with treatment. In terms of the severity of electrolyte imbalances and azotaemia, changes in potassium and bicarbonate levels are also consistent with indicators of response to treatment (Langston, 2008; Drobatz et al., 2008; Elliott et al., 2003). In conclusion, the significant reductions in BUN, creatinine and phosphorus observed with CRRT in cats can be regarded as an indicator of a rapid and effective response to treatment; the downward trend observed in dogs, meanwhile, supports the potential benefit of CRRT and demonstrates that changes in biochemical parameters in CKD can reliably reflect treatment efficacy and clinical response.

In cats undergoing CRRT, the median times to a 50% reduction in biochemical parameters from baseline were approximately 6 hours for BUN and inorganic phosphorus (IP), and 5 hours for creatinine (CRE). These findings indicate that CRRT has a marked effect on biochemical parameters in cats over a short period. In dogs, the median recovery times were calculated as 1 hour for creatinine, 6 hours for BUN, and 4 hours for IP; this indicates that creatinine responds more rapidly to CRRT treatment, whilst recovery in BUN and IP parameters follows a more gradual course. The high baseline values and clinical symptoms reported by Börkü et al. (2000) suggest that clinical recovery is possible alongside a reduction in biochemical parameters following treatment. Similar observations have also been reported in the literature. In a retrospective study by DiBartola et al. (1987), it was reported that biochemical changes in cats with CKD—such as azotaemia, hyperphosphataemia, metabolic acidosis and non-regenerative anaemia—were evaluated in conjunction with clinical and pathological findings. English (1973) and Grollman & Grollman (1959), meanwhile, discussed in detail the decline in glomerular filtration rate, the development of the uraemic syndrome and the occurrence of electrolyte and metabolic imbalances in chronic kidney disease. These studies support the view that the reduction in biochemical parameters observed with CRRT is consistent with the literature and that the treatment response may be clinically significant.

The effect of CRRT treatment on biochemical parameters in cats and dogs was assessed over time using Kaplan-Meier analysis. In this analysis, recovery was defined as a reduction of at least 50% in the relevant parameter compared with its baseline value. According to the Kaplan-Meier results, the median time to improvement in BUN and inorganic phosphorus (IP) levels was 6 hours, and to improvement in creatinine (CRE) levels was 5 hours in cats receiving CRRT. Examination of the curves revealed that biochemical improvement was particularly evident within the first 6 hours of treatment; IP levels showed a rapid decline in the early phase, creatinine became more pronounced in the middle hours, whilst BUN followed a more gradual course. In dogs, the median recovery times were calculated as 1 hour for creatinine, 6 hours for BUN and 4 hours for IP. These findings indicate that creatinine responds more rapidly to treatment in dogs, whilst improvements in BUN and IP levels follow a slower and more gradual course. In general, it can be said that CRRT has a rapid effect on biochemical parameters in cats, whereas in dogs the effect is variable and limited, depending on the parameter. These findings support the view that changes in biochemical parameters in chronic kidney disease (CKD) serve as indicators of treatment response. Similar results have been reported in the literature, and the positive effect of a mineral-restricted diet on biochemical parameters has been highlighted by Brown, O'Brien and Osborne (1991). The pathophysiology of anemia-related biochemical and clinical impairments has been explained by Cowgill (1992), whilst the reduction in glomerular filtration rate and the development of the uraemic syndrome in chronic kidney disease have been discussed in detail by English (1973) and Rubin (1997). The effect of hyperphosphataemia on worsening renal function was demonstrated experimentally by Zager (1982), whilst English (1973) and Grollman & Grollman (1959) detailed the relationship between increases in BUN and creatinine and the loss of renal function, as well as the metabolic and systemic consequences of chronic kidney disease (CKD). This body of literature demonstrates that the effect of CRRT in rapidly reducing biochemical parameters in cats and the parameter-dependent gradual improvement observed in dogs is grounded in pathophysiological principles.

The effect of CRRT treatment on biochemical

parameters in dogs was assessed over time using Kaplan-Meier analysis, and recovery was defined as a reduction of at least 50% in the relevant parameter compared with its baseline value. According to the analysis results, the median time to recovery for the creatinine (CRE) parameter was determined to be 1 hour, and a rapid improvement was observed in the early stages of treatment. In contrast, the median times to recovery for the BUN and inorganic phosphorus (IP) parameters were found to be 6 and 4 hours, respectively, and recovery followed a more gradual course. In a study by Chen et al. (2023), it was also reported that CRRT is a safe and effective treatment method in dogs with acute kidney injury, and that the response to treatment can be monitored using the hourly urea removal rate (URR) and biochemical parameters. The literature indicates that CRRT maintains haemodynamic stability and reduces the risk of dialysis disequilibrium syndrome (DDS) by removing solutes slowly and in a controlled manner (Cowgill, 2011; Cerdá & Ronco, 2009; Ronco et al., 1999; Davenport et al., 1993; Ronco, 2006; Gibney et al., 2008). CRRT efficacy is measured using URR and Kt/V values based on urea kinetic modelling (Basile et al., 2010; Ding et al., 2021; Chamney et al., 2014; Sridharan et al., 2017; Vanholder et al., 2019; Claure-Del Granado et al., 2012; Clark et al., 2017; Schiffl, 2020), with URR reflecting the rate of urea decline during treatment, whilst Kt/V is a more reliable indicator of overall treatment efficacy. Due to variability in urea production rate and solute clearance, URR alone may be insufficient in the later hours; therefore, its use in conjunction with Kt/V is recommended. In the literature, the complication profile of CRRT has been defined as circuit clotting, electrolyte and acid-base disturbances, and complications arising from heparin or citrate (Kovvuru & Velez, 2021; Tolwani, 2012; Brophy et al., 2005; McBride et al., 2019; Uchino et al., 2007; Akhoundi et al., 2015; Buduk et al., 2019; Coady et al., 2019). In our study, life-threatening complications were rare; hemodynamic instability or situations requiring intervention were observed in only a limited number of cases, which demonstrates that CRRT is a safe treatment method when properly monitored. In terms of clinical outcomes, the discharge rate following CRRT in dogs was 53%, with the majority of those discharged being followed up as non-dialysis-dependent (Segev et al., 2008; Segev et al., 2016). Similarly, the CRRT protocol based on the KDIGO guidelines, as reported by Raskansky et al. (2025), was found to be safe and effective in dogs, and it was emphasized that treatment response can be monitored using biochemical parameters. The international consensus guidelines published by Chen et al. (2026) also demonstrate that CRRT results in early and rapid reductions in CRE, alongside gradual decreases in parameters such as BUN and phosphorus, contributing both to the maintenance of haemodynamic stability and to the reduction of the risk of treatment-related complications. In this context, the changes in parameters observed in our study are consistent with the effects of CRRT described in the literature and support the view that the treatment is both safe and effective.

Conclusion

This study investigated the effects of continuous renal replacement therapy (CRRT) on high blood urea nitrogen (BUN) and creatinine (CREA) levels when traditional methods, such as parenteral fluid therapy, were insufficient. The data distribution was assessed using the Shapiro-Wilk test and found not to be normally distributed; therefore, non-parametric statistical methods were employed. Comparisons between treatment groups were performed using the Kruskal-Wallis test; for parameters with a statistically significant difference, post hoc pairwise comparisons were conducted using the Dunn test, and a Bonferroni correction was applied to reduce the risk of Type I error. Baseline biochemical measurements revealed significant differences between cats treated with CRRT and those receiving medical treatment alone. In particular, BUN, creatinine and inorganic phosphorus (IP) levels were found to be higher in cats receiving CRRT compared with the medical treatment group. In dogs, however, baseline values did not differ significantly between the treatment groups. Longitudinal analysis of animals receiving CRRT revealed a marked decrease in BUN, creatinine, and IP levels in cats over the course of treatment. A similar downward trend was observed in dogs; however, these changes were not statistically significant.

A comparison of pre- and post-treatment values confirmed that CRRT resulted in a marked reduction in BUN, creatinine and IP levels in cats; in the group receiving medical treatment, however, the changes were more limited. A measurable reduction in these parameters was also recorded following CRRT in dogs. When biochemical recovery times were examined using a Kaplan-Meier-style analysis, the mean recovery times for BUN and IP in cats were approximately 6 hours, whilst that for creatinine was approximately 5 hours. In dogs, creatinine levels improved more rapidly, with a median recovery time of approximately 1 hour; the times for BUN and IP values to return to normal were approximately 6 and 4 hours, respectively. The findings indicate that CRRT

leads to faster and more pronounced improvements in key renal biomarkers, particularly in cats. These results demonstrate that, in cases of severe renal failure, CRRT offers a potential therapeutic advantage over conventional medical treatment.

The findings of this study have shown that continuous renal replacement therapy (CRRT) is effective in reducing blood urea nitrogen (BUN), creatinine (CREA) and inorganic phosphorus (IP) levels, particularly in cats. In light of this, the following recommendations can be made:

1. In cats and dogs with severe azotaemia and advanced renal failure, particularly in cases where an adequate response to conventional parenteral fluid therapy cannot be achieved, it is recommended that CRRT be considered as a treatment option.
2. The study results have shown that CRRT in cats leads to a more rapid and marked improvement in biochemical parameters. It is therefore thought that the early application of CRRT in cats with chronic or acute kidney injury may improve clinical outcomes.
3. Although the trend towards biochemical improvement observed in dogs was not found to be statistically significant, clinically positive changes were observed. It is therefore recommended that studies with larger sample sizes be conducted to demonstrate the efficacy of CRRT in dogs more clearly.
4. In future research, evaluating not only biochemical parameters but also parameters such as clinical recovery, survival time and quality of life will contribute to a more comprehensive understanding of the clinical efficacy of CRRT.
5. Conducting experimental and clinical studies comparing different durations, flow rates and protocols of CRRT treatment may help to determine the most appropriate conditions for its administration.
6. Planning prospective studies with longer follow-up periods to assess the effects of CRRT on long-term renal function will make significant contributions to the literature.

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