Stability Studies of Cefuroxime in Peritoneal Dialysis Solution by Using the HPLC Method

[1,2]Nosheen Tabassum, [1]Noor ul Amin Mohsin*, [1]Humna Akram and [1]Muhammad Shan
[1]*Department of Pharmaceutical Chemistry, Faculty of Pharmaceutical Sciences, Government College University Faisalabad, Pakistan.*
[2]*Tehsil Head Quarter (THQ) Hospital Chak Jhumra, Faisalabad, Punjab, Pakistan*.
noorulamimmohsin@yahoo.com*

(Received on 21st June 2023, accepted in revised form 2nd January 2024)

Summary: Peritoneal dialysis is a technique for blood purification and is used in chronic kidney disease. Peritonitis is a major problem linked to peritoneal dialysis which limits its utilization. Cephalosporins are extensively used for the treatment of peritoneal dialysis-related peritonitis. Cefuroxime is the second-generation cephalosporin that is used for the prevention and cure of peritonitis. The stability of cefuroxime in peritoneal dialysis solution was investigated after storage at different temperatures. Cefuroxime in different concentrations (250 mg, 750 mg and 1.5 g) was injected into the bags of peritoneal dialysis solution which were stored at 4 °C, 25 °C, and 40 °C. Samples were taken at regular intervals and evaluated by a validated HPLC method. Cefuroxime remained stable for fourteen days at 4 °C and the pattern of stability was the same for all concentrations of cefuroxime. At 25 °C, cefuroxime remained stable for 24 hours in isotonic and hypertonic PD solutions and maintained more than 90% of its initial concentrations. At 40 °C, cefuroxime remained stable for 6.7 and 6.0 hours in isotonic and hypertonic PD solutions respectively. The degradation of cefuroxime was higher in hypertonic solutions as compared to isotonic solutions.

Keywords: Peritoneal dialysis solution, Peritonitis, HPLC, Temperature, Concentration.

Introduction

Chronic kidney diseases have increased as a result of the increase in blood pressure, diabetes, overweight, dyslipidemia, physical inactivity, and smoking [1, 2]. Peritoneal dialysis (PD) is used in chronic kidney disease if transplantation is not available or inappropriate [3, 4]. PD is a safe and inexpensive method for blood purification in the management of acute kidney injury. PD is widely used in countries like Hong Kong, Mexico, New Zealand, and Qatar [5]. PD is especially useful for developing countries where limited resources are available and the cost of therapy is problematic [6-8]. PD provides a better standard of living and has similar results as hemodialysis (HD). The cost of PD is less as compared to HD in most developed countries. However, PD is utilized in less than one percent of these patients due to poor survival and high infection rates including peritonitis [9]. The safety of this technique may be an issue for not adopting this therapy. Peritonitis is a vital problem of PD which may lead to severe consequences [10, 11]. It also restricts the use of this vital dialysis modality and is the main reason for PD technique failure and shifting of patients to HD [12, 13]. Staphylococcal species are the most common organisms that are involved in more than 50% of cases of peritonitis [14, 15]. Innovations in the technology of PD modality have remarkably reduced complications and patients can be maintained on PD for longer times [16]. According to some studies, better dialysis practices can increase patient survival [17]. With the emergence of the covid-19 pandemic, home-based PD therapy will be more beneficial and will protect individuals from spreading infection into the community resulting in low morbidity and mortality rate [18]. Aminoglycosides, cephalosporin, penicillins, fluoroquinolones, and vancomycin are the first-line therapeutic agents for peritoneal dialysis-related peritonitis (PDRP) [19]. The stability of antibiotics in PD solutions is a major issue that can affect the health of patients undergoing dialysis. The stability of antibiotics is affected by storage conditions. Therefore, there is a need to assess the stability of antibiotics in peritoneal dialysis solution. The antibiotic activity may decrease due to the storage for a longer time at higher temperatures.

Cefuroxime sodium **(**Fig 1**)** is a broad-spectrum, second-generation, semisynthetic cephalosporin with favourable pharmacokinetic properties [20]. Cefuroxime is used in combination with other drugs for the treatment of peritonitis and has successfully replaced gentamicin [21, 22]. The efficacy of cefuroxime is due to the high concentration achieved at the site of IP administration. Cefuroxime can also be used prophylactically to minimize the risk of microbial growth and peritonitis in continuous ambulatory peritoneal dialysis. Cefuroxime is a commonly used antibiotic in the government sector of Pakistan. No study has been conducted for its stability in peritoneal dialysis solution.

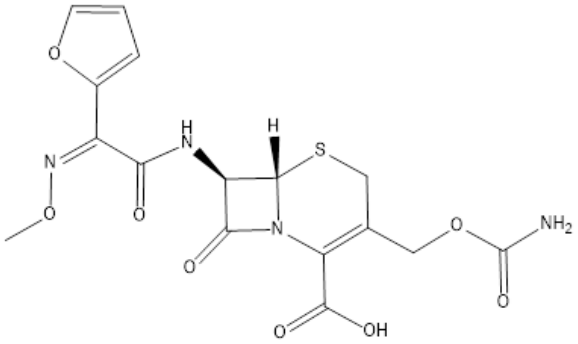

Fig. 1: Structural formula of cefuroxime.

High-performance or high-pressure liquid chromatography (HPLC) is used for the separation, identification, and quantification of compounds in solution. HPLC is also known as liquid chromatography (LC). HPLC is one of the most commonly used techniques for quantitative analysis in pharmaceutical industries and drug testing laboratories. In an HPLC system, the stationary phase may be made up of microporous particles, thus, small particle size and a high-pressure pump are required for the mobile phase solvent to pass through the stationary column with sufficient driving force [23, 24].

This study aimed to analyze the stability of cefuroxime in peritoneal dialysis solution after storage at the temperature of 4 ºC, 25 ºC, and 40 ºC. The assay of cefuroxime was performed by using the HPLC method. The effect of the concentration of cefuroxime and dextrose on the stability of cefuroxime was also determined.

Experimental

Equipment and chemicals

Reverse phase HPLC (RP-HPLC) system (Waters Alliance model e2695 equipped with PDA detector model 2998 and operated via software (Empower 3), USA), refrigerator (Caravell model MEC-1200), hot air oven (UN55 Memmert, Germany), filtration assembly with 0.45 µM membrane filters (Schott Duran), ultrasonic bath (UCP-10 Germany), analytical weighing balance (Mettler Toledo), cefuroxime injection (250 mg, 750 mg and 1.5 g batch W52Y, SK8S, AJ7L respectively) packed with water for injection (WFI) (Zinacef, GSK Pakistan, Limited), cefuroxime sodium (standard) (91.95%) was donated by Shenzhen Salubris Pharmaceutical Co Ltd – China, isotonic (1.65%) and hypertonic (7.7%) peritoneal dialysis solution (1000 ml PVC bag, Medipak Limited having batch 004254B & 002157B respectively), syringe filters (0.22 µM, sartorius), disposable syringes (5 ml & 10 ml), sodium acetate trihydrate (laboratory reagent grade), acetic acid (laboratory reagent grade), acetonitrile (HPLC grade), glassware like glass pipette, measuring cylinder, volumetric flask, beaker (Pyrex class A).

Preparation and storage of cefuroxime peritoneal dialysis mixtures

Three bags for each isotonic and hypertonic peritoneal dialysis solution were taken. Added 250 mg, 750 mg, and 1.5 g of cefuroxime in isotonic and hypertonic peritoneal dialysis solution. Each concentration was tested in isotonic and hypertonic solutions. The isotonic and hypertonic peritoneal dialysis solution bags were stored at 4 ºC, 25 ºC, and 40 ºC [25, 26]. Studies were conducted for 14 days and samples were observed visually and tested for percentage contents by using HPLC methods.

Preparation of sample solution

Samples of cefuroxime were prepared by reconstitution of cefuroxime i.e. 250 mg, 750 mg, and 1.5 g with 2 ml, 6 ml, and 10 ml water for injection (WFI) respectively. Solutions were drawn using 5 ml and 10 ml syringes and injected into PVC bags containing 1000 ml of isotonic peritoneal dialysis solution. The bags were shaken for one minute for complete mixing. Similar solutions were prepared in hypertonic peritoneal dialysis solution. The final concentrations of cefuroxime in PVC bags were 0.25 mg/ml, 0.75 mg/ml and 1.5 mg/ml for 250 mg, 750 mg and 1.5 g samples respectively. All samples was prepared in triplicate to determine the concentration of cefuroxime.

Storage of samples

Total of eighteen samples of admixture were prepared and stored at particular temperatures for fourteen days as under:

Three bags of cefuroxime (one each for 0.25 mg/ml, 0.75 mg/ml and 1.5 mg/ml) in isotonic peritoneal dialysis solution and three bags (one each for 0.25 mg/ml, 0.75 mg/ml and 1.5 mg/ml) in hypertonic peritoneal dialysis solution were stored at 4 ºC.

Three bags of cefuroxime (one for each) in isotonic peritoneal dialysis solution and three bags (one for each) in hypertonic peritoneal dialysis solution were stored at 25 ºC.

Three bags of cefuroxime (one for each) in isotonic peritoneal dialysis solution and three bags (one for each) in hypertonic peritoneal dialysis solution were stored at 40 ºC.

Collection of samples

At the start of the analysis, 2 ml of sample solutions were taken from each concentration. Then 2 ml of samples were taken at intervals of 1, 2, 4, 6, 12, 24, 48, 72, 96, 120, 168, and 336 hours. The bags were shaken thoroughly before the collection of sample solutions and sterile syringes were used to maintain the sterility of the samples. Samples were transferred into test tubes and stored at -20 ºC before analysis.

Analytical method for determination of percentage contents

An HPLC method adopted by Li et al. was used for the determination of the percentage contents of cefuroxime [27]. Following chromatographic conditions were used for the assay.

column: A spherisorb column (C18) of stainless steel (particle size 5 µm, 250 mm length, 4.6 mm internal diameter). The retention capacity of the C18 column is greater than C04 and C08 columns due to the increased number of carbon chains. It is more hydrophobic than C04 and C08 columns; mobile phase: 0.05 M sodium acetate buffer solution, acetonitrile (90:10); flow rate: 1.5 ml/min; absorbance wavelength: 273 nm; temperature: 25 ºC

Preparation of mobile phase

Sodium acetate trihydrate (6.8 g) was dissolved in a small amount of pre-filtered distilled water. The volume was made up to 1000 ml with pre-filtered distilled water. The buffer solution and acetonitrile were mixed in a ratio of 90:10 to get the final mobile phase. The mobile phase was filtered through a filtration assembly of 0.45 µM size. The mobile phase was kept in the ultrasonic bath for degassing.

Preparation of standard cefuroxime solution

The standard cefuroxime was used in this study to check the validity of the procedure. Cefuroxime Sodium (Standard) (91.95%) was donated by Shenzhen Salubris Pharmaceutical Co Ltd – China.

The standard cefuroxime solution (0.1%) was prepared by dissolving 27.2 mg of cefuroxime in a small amount of isotonic solution. The final volume was made up to 25 ml in a volumetric flask with an isotonic solution.

Procedure

The standard solution of cefuroxime (20 µl) was injected into the HPLC column through an autosampler. The flow rate was adjusted at the rate of 1 ml/min for 30 min. The flow rate was adjusted to comply with system suitability parameters. The relative standard deviation (RSD) should not be less than 2.2, the theoretical plate count should not be less than 2000 and the peak tailing factor should not be more than 2. Then flow rate was increased to 1.2 ml/min and finally to 1.5 ml/min to improve system suitability parameters (Fig **2**). A photodiode detector (200-800 nm) was used to detect cefuroxime at the wavelength of 273 nm.

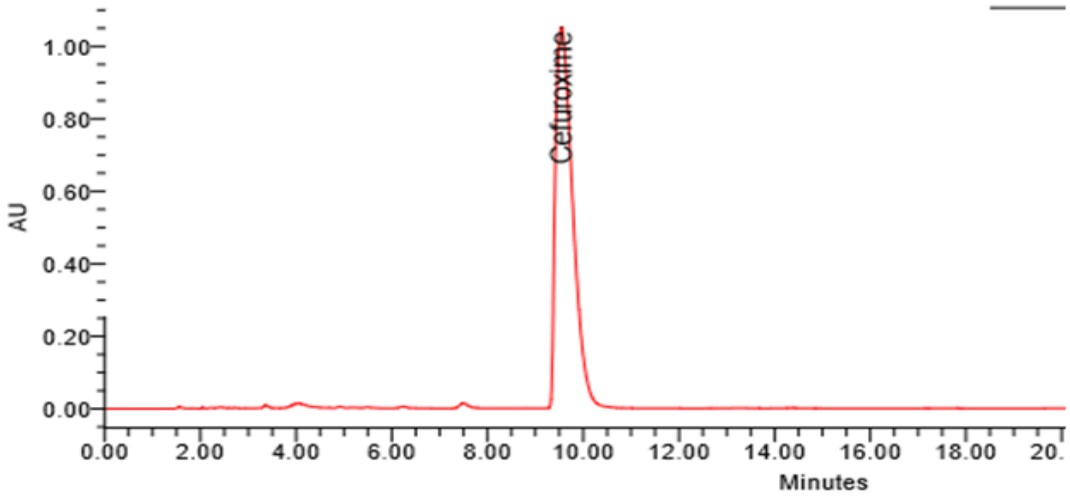

Fig. 2: Chromatogram of standard of cefuroxime at a flow rate of 1.5 ml/min.

Preparation of calibration curve for cefuroxime in isotonic and hypertonic PD solution

Stock solutions of cefuroxime were prepared in isotonic and hypertonic PD solutions having a concentration of 2 mg/ml. Seven dilutions were prepared from standard stock solution for both isotonic and hypertonic solutions having concentrations of 1.75 mg/ml, 1.5 mg/ml, 1.0 mg/ml, 0.75 mg/ml, 0.25 mg/ml, 0.15 mg/ml and 0.1 mg/ml. Calibration curves were constructed by plotting the mean response against the concentration of cefuroxime.

Repeatability

Repeatability or intra-assay precision was determined by measuring the response of the same concentration of cefuroxime using the same chromatographic conditions and instruments on consecutive two days. Stock solutions of cefuroxime having a concentration of 1 mg/ml were prepared in isotonic PD solution and hypertonic PD solution on the first day of the study. Six replicates of 0.75 mg/ml concentration of cefuroxime were prepared in isotonic PD solution on consecutive days. Similarly, six replicates of 0.75 mg/ml concentration of cefuroxime were prepared in hypertonic PD solution. Solutions were analyzed immediately after preparation by injecting 10 µl of standard solution and response was calculated. Results were tabulated and standard deviation (SD) values were calculated from tables using statistical tools. The repeatability was ensured by ensuring that the percentage relative standard deviation (% RSD) was less than 2 on consecutive days.

Stability-indicating property of assay method

A commercial sample of 750 mg cefuroxime was reconstituted with water for injection (WFI) according to the manufacturer's instructions and transferred into a 50 ml volumetric flask. The volume was adjusted with PD solution to yield a nominal concentration of 15 mg/ml. An aliquot of 6.7 mL was pipetted into each of two 100 ml volumetric flasks and adjusted to volume with PD solution. It produced an approximate concentration of 1 mg/ml. 1 ml sample was taken in triplicate from each flask and analyzed immediately to measure the initial concentration of cefuroxime. Then, these two flasks were sealed with aluminum foil and heated for 1 hour at 70 ºC. Triplicate samples from each flask were analyzed to measure the concentration of cefuroxime remaining in the solution and observe additional peaks (if any) of likely degradation products of cefuroxime.

Analysis of cefuroxime PD admixtures

For the analysis of cefuroxime, samples collected at various intervals were thawed at room temperature. The samples were injected into glass HPLC vials using syringe filters of 0.22 µM size. The glass HPLC vials were kept in auto-samplers for further analysis by HPLC according to the above-mentioned conditions. The temperature of the auto-sampler was adjusted at 10 ºC. Each sample stored at different temperatures was analyzed by using HPLC. The peak of cefuroxime was identified by correlating the retention time (RT) of the sample with the standard drug. The concentration of cefuroxime was decided from the calibration curve by taking the initial concentration at 100%. The instability was indicated in case of loss of more than 10% of initial concentration.

Result and Discussion

Calibration curve

The standard solution of each concentration in isotonic and hypertonic PD solution was analyzed. The calibration curve constructed between the detector response and concentration of cefuroxime sodium is shown in Fig **3**. Standard solutions of cefuroxime gave linear responses for each concentration in the range of 0.1-1.75 mg/ml with a correlation coefficient of 0.9998.

Repeatability

The repeatability of the assay method was measured by determining the concentration of cefuroxime in isotonic and hypertonic PD solution (n = 6) on two consecutive days. Results of the precision of cefuroxime in isotonic PD solution on day 1 and day 2 are shown in Table 1. Standard deviation (S.D.) values were calculated using statistical tools from tables and were found to be 0.529% and 0.810% on day 1 and day 2, respectively in isotonic PD solution. The above results meet the required specification i.e. less than 2% and suggest excellent repeatability of the assay method.

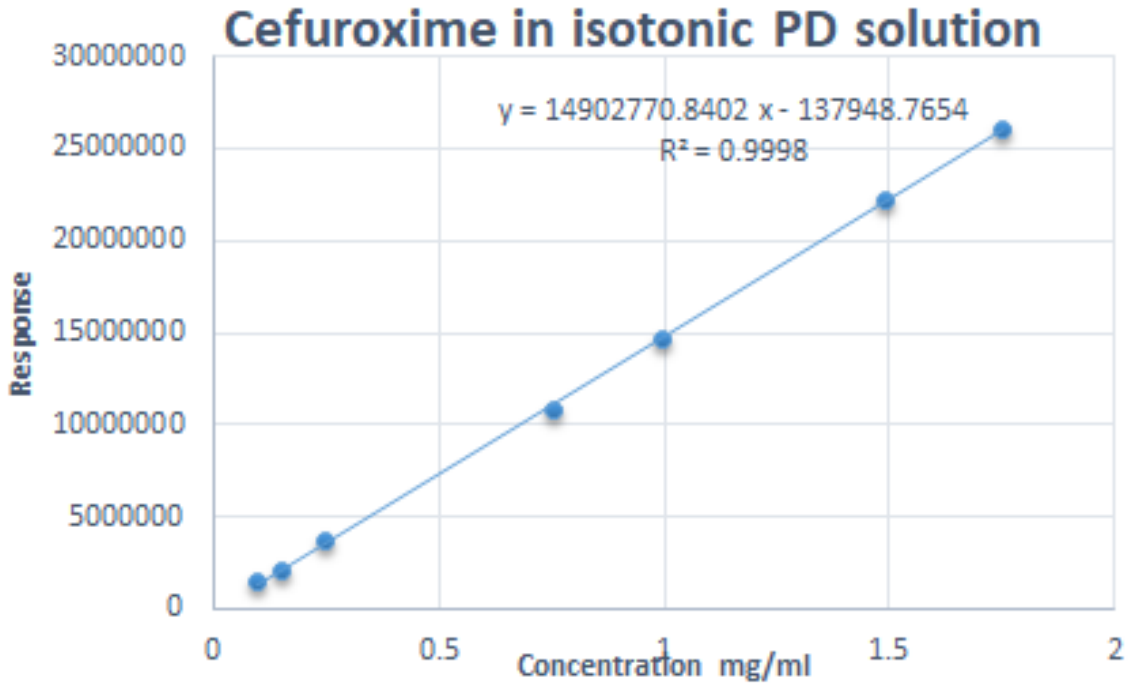

Fig. 3: Calibration curve for cefuroxime sodium in isotonic PD solution.

Stability indicating HPLC method

Cefuroxime solutions in isotonic PD solution containing 1 mg/ml of the drug were analyzed before and after heating at 70 ºC. Their peaks were compared. Chromatograms of cefuroxime in PD solution tested immediately after preparation and heated for 1 hour at 70˚C are represented in Fig **4**. Changes evident from the chromatogram of heated solutions include a reduction in the peak height of cefuroxime and an increase in the heights of other peaks between 6 to 8 minutes after injection. After heating at 70 ºC, the concentration of cefuroxime remaining in the PD admixture was found to be 84.6 %, of the initial concentration measured in solution (a). The degraded products peak did not interfere with the cefuroxime peak and separated well from the cefuroxime peak. Thus, the above assay method is a suitable stability-indicating assay method for cefuroxime and can detect a decrease in the concentration of cefuroxime caused by its degradation in extreme storage conditions.

Physical inspection

Sample solutions were periodically checked for physical changes like colour, turbidity, precipitation, and particulate matter. No colour change was observed for samples stored at 4 ºC, while at 25 ºC, a colour change from faint yellow to yellow and dark yellow was observed from day 5. The samples stored at 40 ºC showed a colour change from faint yellow to yellow and dark yellow from day 2. All solutions remained clear and showed no precipitation or particulate matter.

Table-1: Repeatability/Intraday precision of cefuroxime in isotonic PD fluid.

Concentration	Replicates	AUC (Day 1)	AUC (Day 2)
0.75 mg/ml	Replicate 1	10879591	11956630
	Replicate 2	10841151	11864051
	Replicate 3	10819430	11741533
	Replicate 4	10780048	11906117
	Replicate 5	10714272	11835891
	Replicate 6	10784962	11706382
	Mean	10803242.28	11835100.65
	S.D.	57124.70885	95890.35716
	%RSD	0.528773746	0.81022004

AUC= area under the curve

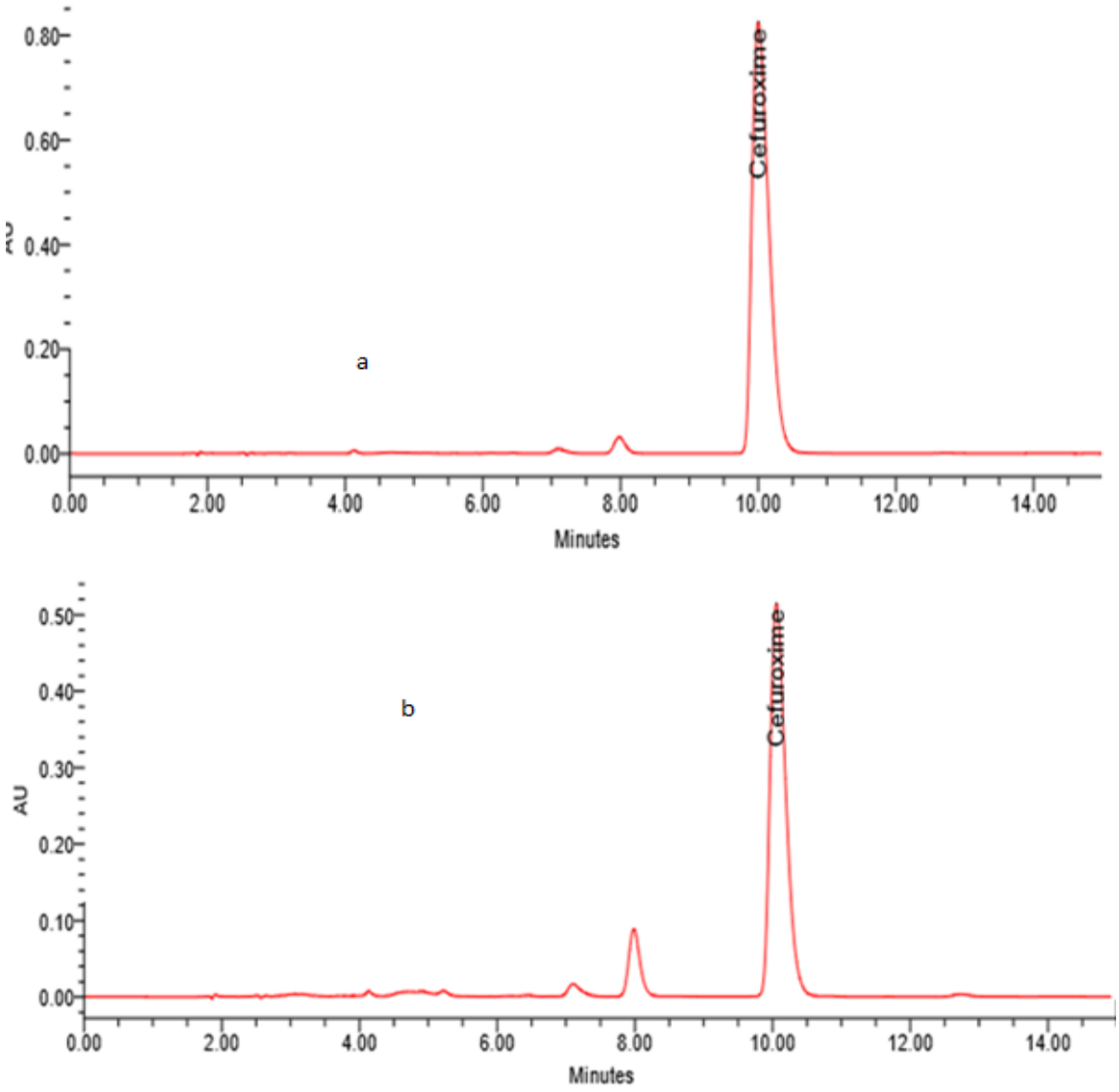

Fig. 4: Cefuroxime in PD solution assay a) immediately after preparation and b) after heating at 70°C.

Analysis of cefuroxime by HPLC

Samples stored at different temperatures were examined by HPLC to determine the percentage contents. The concentration of cefuroxime was calculated from the calibration curve. The concentration at zero time was taken as 100% while the concentrations of subsequent samples were expressed as a percentage of initial concentrations. Cefuroxime was considered stable if it maintained more than 90% of its initial concentration. All concentrations of cefuroxime remained stable at 4 °C (Table-2) during the study period of fourteen days and retained more than 92% of initial concentrations [28, 29].

A similar pattern of stability was observed in the case of isotonic and hypertonic solutions. At 25 °C, cefuroxime remained stable for 24 hours (Fig **5**) and then the concentrations decreased rapidly (Table-3). The concentration of cefuroxime dropped to 50% after seven days of storage. Although all concentrations showed a similar degradation pattern, the degradation was more rapid in hypertonic as compared to isotonic solution. The concentration of cefuroxime dropped to less than 25% after 14 days of study.

Table-2: Mean concentration of cefuroxime in isotonic PD solution after storage at 4°C % IC percentage of initial concentration.

Time (hrs)	250 mg		750 mg		1.5 g	
	Mean Conc.	%IC	Mean Conc.	%IC	Mean Conc.	%IC
0	0.247	100.0	0.731	100.0	1.461	100.0
1	0.246	99.6	0.730	99.86	1.458	99.8
2	0.246	99.6	0.730	99.86	1.458	99.8
4	0.246	99.6	0.729	99.73	1.453	99.5
6	0.245	99.2	0.729	99.73	1.452	99.4
12	0.245	99.2	0.726	99.32	1.452	99.4
24	0.244	98.8	0.723	98.91	1.445	98.9
48	0.244	98.8	0.723	98.91	1.441	98.6
72	0.242	98.0	0.712	97.40	1.431	97.9
96	0.239	96.8	0.712	97.40	1.421	97.3
120	0.237	96.0	0.707	96.72	1.413	96.7
168	0.235	95.1	0.689	94.25	1.392	95.3
336	0.228	92.3	0.678	92.75	1.347	92.2

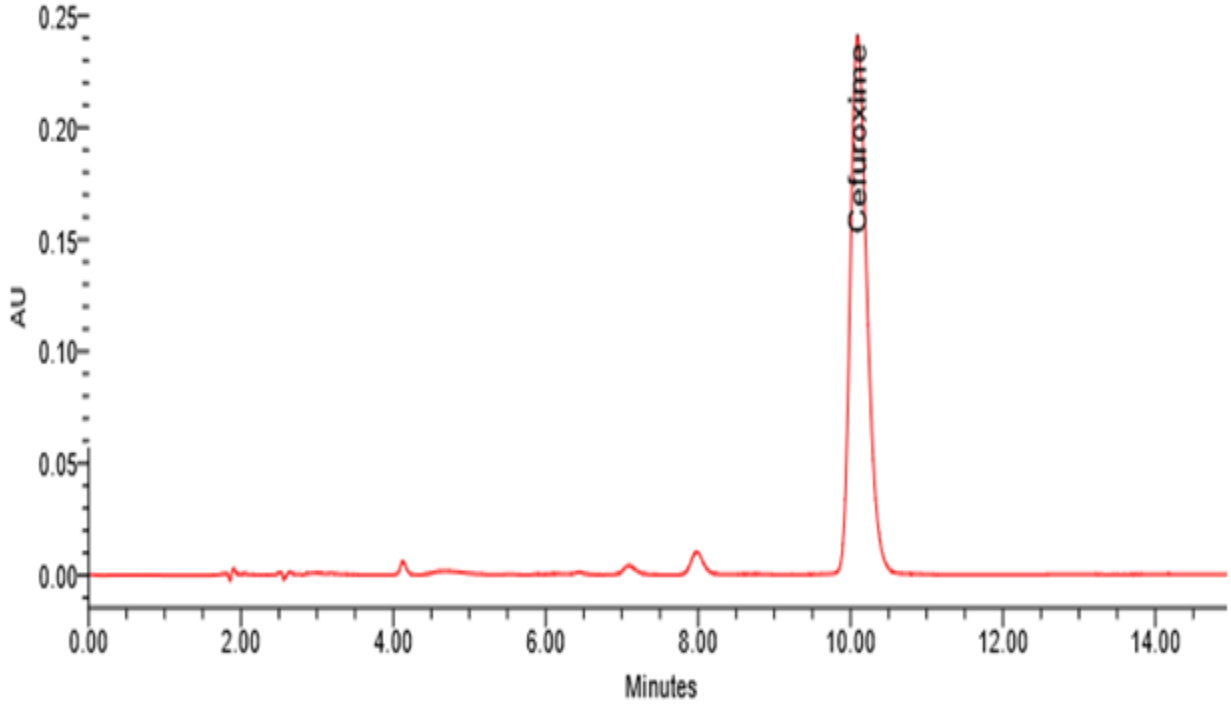

Fig. 5: Chromatogram of 250mg cefuroxime in isotonic PD solution at 25.

Table-3: Mean concentrations of cefuroxime in isotonic PD solution after storage at 25°C.

Time (hrs)	250 mg		750 mg		1.5 g	
	Mean Conc.	%IC	Mean Conc.	%IC	Mean Conc.	%IC
0	0.242	100.0	0.727	100.0	1.457	100.00
1	0.241	99.59	0.725	99.72	1.451	99.32
2	0.238	98.35	0.712	97.94	1.439	98.49
4	0.238	98.35	0.712	97.94	1.431	97.95
6	0.235	97.11	0.708	97.39	1.412	96.65
12	0.229	94.63	0.686	94.36	1.362	93.22
24	0.224	92.56	0.669	92.02	1.344	91.99
48	0.207	85.54	0.617	84.87	1.261	86.31
72	0.185	76.45	0.563	77.44	1.121	76.73
96	0.163	67.36	0.497	68.36	0.978	66.94
120	0.136	56.20	0.409	56.26	0.856	58.59
168	0.123	50.83	0.371	51.03	0.715	48.94
336	0.063	26.03	0.186	25.58	0.373	25.53

Table-4: Mean concemtration of cefuroxime in isotonic PD solution stored at 40°C.

Time (hours)	250 mg		750 mg		1.5 g	
	Mean Conc.	%IC	Mean Conc.	%IC	Mean Conc.	%IC
0	0.245	100	0.738	100	1.439	100.00
1	0.243	99.18	0.727	98.51	1.439	100.00
2	0.239	97.68	0.723	97.97	1.433	97.09
4	0.234	95.51	0.709	96.07	1.421	96.27
6	0.229	93.47	0.692	93.77	1.391	94.24
12	0.213	86.94	0.631	85.50	1.248	84.55
24	0.175	71.43	0.499	67.62	1.019	69.04
48	0.117	47.76	0.332	44.99	0.681	46.14
72	0.078	31.84	0.206	27.91	0.452	30.62

At 40 ºC, cefuroxime showed stability for six-hour only and then there was a significant loss of potency within 12 hours (Table-4). The concentrations of cefuroxime dropped to 71.43% and 47.76% after 24 and 48 hours respectively. The drug showed a significant degradation after 24 and 48 hours (Fig **6**). In the case of hypertonic solution, the concentration of cefuroxime was found to be 71% and 40% after 24 and 48 hours.

Order of reaction

The study showed that the concentration of cefuroxime decreased with the increase in temperature. The order of reaction of cefuroxime degradation was determined at 4 °C, 25 °C, 40 °C The degradation of cefuroxime followed a first-order kinetic for isotonic as well as hypertonic solution (Fig **7**). The values of the correlation coefficient were almost equal to one for all graphs. The slope of the plot was lowest at 4 °C and highest at 40 °C which showed that degradation was highest at 40 °C and lowest at 4 °C. There was no effect of concentration on the rate of degradation of cefuroxime and the drug followed first-order kinetics in hypertonic PD solutions.

Arrhenius plot

The effect of temperature on the reaction rate was investigated using the Arrhenius plot of

degradation rate constant. The Arrhenius plot was constructed between the inverse of temperature (1/T) and the natural log of degradation rate constants (ln K) which was determined from the slope of first-order reactions. From the Arrhenius plot, it was determined that values of k are more at 40 ºC and less at 4 ºC. This shows that the drug degrades rapidly at high temperature. In a hypertonic solution, the value of K is slightly higher than in an isotonic solution (Fig **8**)

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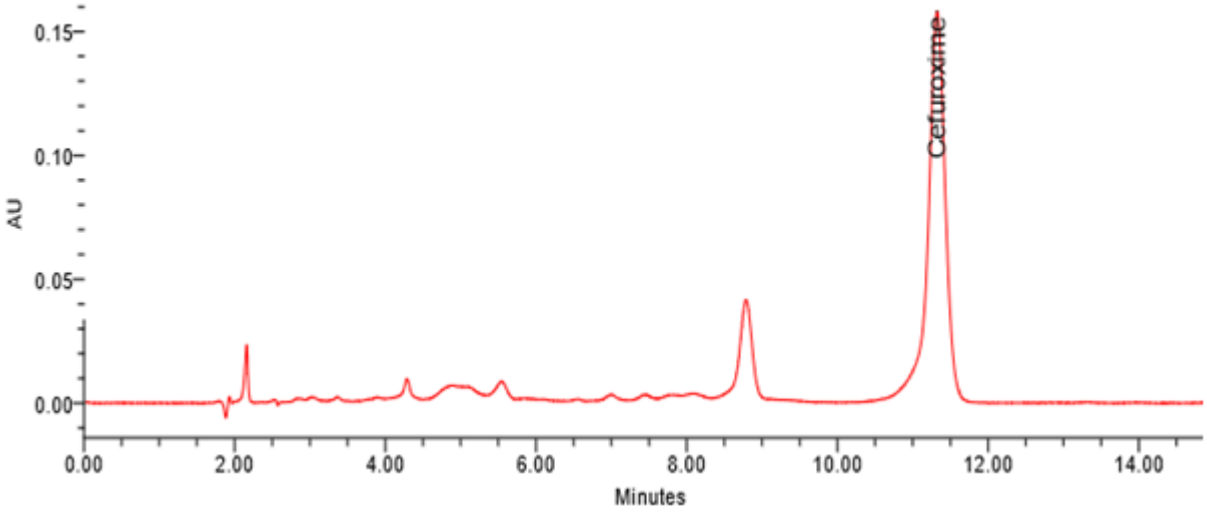

Fig. 6: Chromatogram of 250mg cefuroxime in hypertonic PD solution after 24 hours at 40°C.

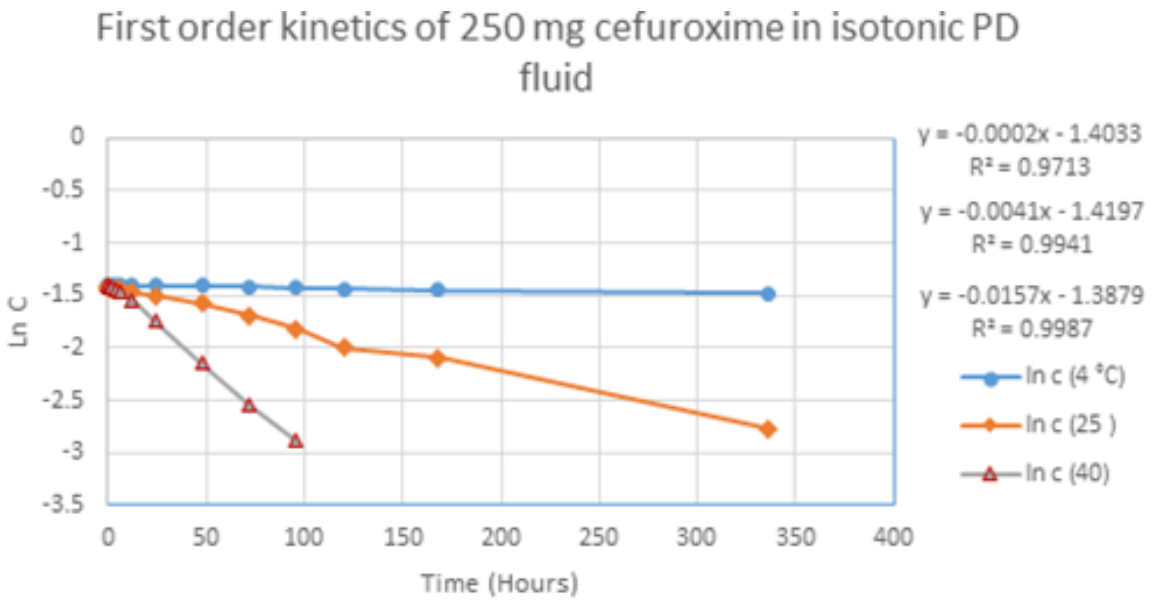

Fig. 7: First order plot for 250mg cefuroxime in isotonic PD solution.

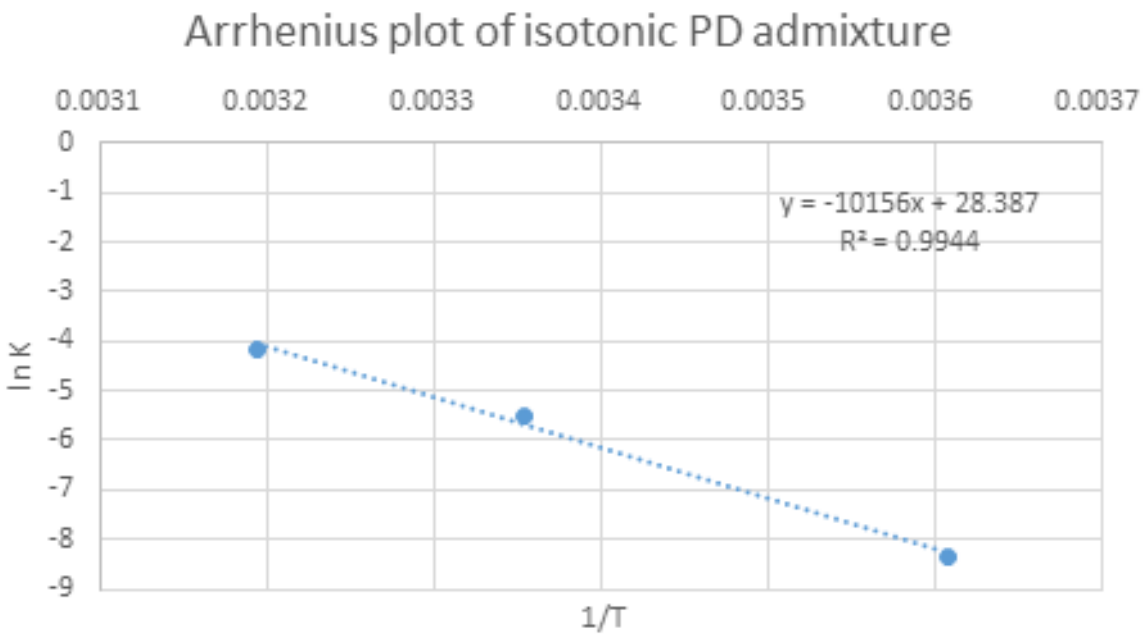

Fig. 8: Arrhenius plot for isotonic PD solution

PDRP is the major cause of morbidity that leads to hospitalization [16, 30]. PDRP is often treated by using cephalosporins. Therefore the stability study of cephalosporins in peritoneal dialysis solution is very significant [31]. The stability of cefuroxime in isotonic and hypertonic peritoneal dialysis solutions was examined. The pattern of stability of cefuroxime was the same for all concentrations i.e. 250 mg, 750 mg and 1.5 g. At 25 ºC, cefuroxime retained greater than 90% of its initial concentration in the isotonic PD admixture for 25 hours and in hypertonic PD admixture for 24 hours. At 40 ºC, cefuroxime remained stable for 6.7 hours in isotonic PD admixture and 6.0 hours in hypertonic PD admixture. From the chromatograms of tested solutions, an increase in the height of the peak of degradation products and a decrease in the height of the cefuroxime peak were observed with the increased degradation of cefuroxime. Therefore the stability studies of cefuroxime showed that the drug degrades more quickly at elevated temperature. The PD fluid showed no precipitation or particle formation and therefore degradation products of cefuroxime were soluble in the PD fluid. Degradation of cefuroxime in PD solutions follows first-order kinetics at all storage temperatures. The higher kinetic energy of the molecules, which results in a more molecular collision, is responsible for the increased degradation of the drug at high temperatures. The drug had a shorter shelf life at higher temperatures due to the faster rate of degradation. The degradation of drug was also slightly higher in the hypertonic PD solution, which can be explained by the results of the frequency factor. In hypertonic PD solution, the value of frequency factor was greater than that in isotonic PD solution. The study showed that the method used is accurate and reproducible. This method can be used to study the degradation products of cefuroxime in peritoneal dialysis solution. The stability studies of cefuroxime can guide practitioners to use this drug in PD solutions for the treatment of PDRP.

Conclusion

Currently, the PD is less commonly used in Pakistan. The safety of this technique may be an issue for not adopting this therapy. The present investigations were carried out to determine the stability of cefuroxime in PD solution stored at different temperatures. Cefuroxime showed more degradation at high temperature. Cefuroxime remained stable for fourteen days, twenty-four hours and six hours at 4 °C, 25 ºC and 40 °C. The degradation of cefuroxime was comparatively higher in hypertonic solutions as compared to isotonic solutions. Therefore cefuroxime can be used for inpatient and outpatient treatment of PDRPs for up to 14 days after admixture and no adjustment in dose is required when stored at refrigerator temperature (4 ºC). However, when the drug has to be administered in a warmed environment or warmed to body temperature (37 ºC), cefuroxime-containing PD solution should be used immediately after admixture when a glucose-containing PD solution is used. In the

future, samples for the stability studies should be collected from the different hospitals having PD facilities. The stability studies of such samples will help to assess the safety of PD solutions in a better way. In developing countries like Pakistan, PD is much better option than the HD due to the limited availability of resources. It can help the patients by reducing the economic burden. Therefore PD should be considered as a choice for people undergoing treatment for chronic kidney diseases.

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