Journal of
Biomedical and Biological Sciences

Review Article Open Access

Clinical Pharmacology of Ceftriaxone in Paediatrics

Gudisa Bereda[1*]

[1]Department of Pharmacy, Negelle Health Science College, Guji, Ethiopia.

[*]**Corresponding Author:** Bereda G, Department of Pharmacy, Negelle Health Science College, Guji, Ethiopia. Email: gudisabareda95@gmail.com

Citation: Bereda G. Clinical Pharmacology of Ceftriaxone in Paediatrics. Journal of Biomedical and Biological Sciences. 2022;2(1):1-8.

Received Date: 11th February, 2022 **Accepted Date:** 26th March, 2022 **Published Date:** 2nd April, 2022

Abstract

Background: Ceftriaxone is a parenteral cephalosporin with broad antimicrobial activity. Ceftriaxone, a third-generation cephalosporin, is familiarly used for the management of solemn infections in critically ill pediatric patients owing to its importance's i.e., a broad spectrum of activity, substantial resistance to beta-lactamases, good penetration into tissues, predictable and sufficient plasma concentrations for therapeutic effect, and a prolonged half-life. Ceftriaxone is a bactericidal agent that acts by suppressing of bacterial cell wall generation. Ceftriaxone should not be mixed with calcium-containing products and not administered in the similar or different infusion lines or sites in every patient within forty-eight hours of each other (5 ceftriaxone half-lives). **Objective:** To encapsulate the backgrounds, pharmacokinetics, mechanisms of action, indications, adverse drug reaction, contraindications, and drug interaction of ceftriaxone in pediatrics or to recapitulate the clinical pharmacology of ceftriaxone in pediatrics. **Methodology:** The author used 51 different published articles for the accomplishment of this review article. Google search engine was used for accessing published articles from databases like Google Scholar, EMBASE, Research Gate, Scopus database, Scielo, PubMed, NCBI, NDSS, PMID, PMCID, Science direct, Cochrane library, Lancet, Cochrane Database and CLINMED international library. **Finding:** The consummate ubiquitous adverse drug reaction consociated with administrating ceftriaxone involve allergic reactions (rash, eosinophilia, fever, anaphylactoid shock, etc); gastrointestinal disturbances, and temporary escalate in transaminases, nephrotoxicity, pseudomembranous colitis, blood dyscrasias, hematological anomalies. Ceftriaxone displays bilirubin from albumin attaching sites; ceftriaxone generated escalate of free bilirubin and erythrocyte-attached bilirubin and de-escalate of unconjugated bilirubin. Coadministration of ceftriaxone and calcium containing solutions or products in a child < a month old is contraindicated: ceftriaxone reacts to calcium-containing solution and it can chelate in lungs and kidneys of a child < twenty-eight days years and this could be life-threatening. **Conclusion:** Coincident administrations of ceftriaxone with aminoglycosides such as gentamycin and loop diuretics (furosemide) perhaps escalate the peril of nephrotoxicity (hast degeneration in the kidney work owing to the toxic outcome of dual or triple medications).

Keywords: Ceftriaxone; Clinical; Paediatrics; Pharmacology

Journal of
Biomedical and Biological Sciences

Review Article Open Access

Introduction

Ceftriaxone is a parenteral cephalosporin with broad antimicrobial activity. Ceftriaxone is an antibiotic which is familiarly used to manage infections caused by bacteria [1]. Ceftriaxone, a third-generation cephalosporin, is familiarly used for the management of solemn infections in critically ill paediatric patients owing to its importance's i.e., a broad spectrum of activity, substantial resistance to beta-lactamases, good penetration into tissues, predictable and sufficient plasma concentrations for therapeutic effect, and a prolonged half-life [2]. Ceftriaxone is broadly used in paediatric patients of all ages. Ceftriaxone sodium is a white to yellowish crystalline powder which is readily soluble in water, sparingly soluble in methanol and very slightly soluble in ethanol. The pH of a 1% aqueous solution is approximately 6.7. Ceftriaxone sodium is (6R, 7R)-7-[2-(2-Amino-4-thiazolyl) glyoxylamido]-8-oxo-3-[[(1,2,5,6-tetrahydro-2-methyl-5,6-dioxo-as-triazin-3-yl) thio] methyl]-5-thia-1-zabicyclo [4.2.0] oct-2-ene-2-carboxylic acid, 72-(Z)- (O-methyl oxime), disodium salt, sesquihydrate. Ceftriaxone is an injectable cephalosporin with wide anti-infective spectrum and has extended elimination $t1/_2$ of eight hrs [3]. Ceftriaxone is only available as an injection and is given through a small plastic tube (cannula) intravenously (into a vein). Ceftriaxone is usually given 1 time each day. Ceftriaxone is extremely attached to plasma proteins (97%), but in infants can replace bilirubin from its protein binding sites and exacerbate physiological jaundice. They are most commonly used in hospitalized patients for prophylaxis because of their broad spectrum of activity. The agents are frequently used inappropriately for both prophylaxis and empirical management because physicians' dearth knowledge of their real spectrum of activity [4]. Ceftriaxone distributes broadly in CSF, bile, bronchial synthesis, lung tissue, ascitic fluid, and middle ear [5].

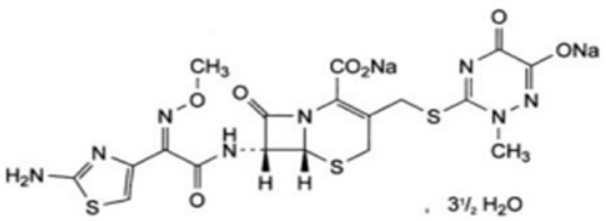

Figure 1: chemical structure of ceftriaxone disodium

Literature Review

Pharmacokinetics: Ceftriaxone was completely absorbed following IM administration with mean maximum plasma concentrations occurring between 2- and 3-hours post-dose. Multiple IV or IM doses ranging from 0.5 to 2 gm at 12- to 24-hour intervals resulted in 15% to 36% accumulation of ceftriaxone above single dose values. Ceftriaxone has a longer $t1/_2$ than other cephalosporins; the plasma t1/2 falls from fifteen hours at birth to a value solely a little in surplus of that resulted in adults (7 hours) over certain 2-4 weeks. Ceftriaxone is eliminated unchanged by dual biliary (40%) and renal mechanisms [6]. The remainder is generated unchanged in the bile. Serum $t1/_2$ in infants born before the normal time is five to sixteen hrs. Only for infants who have hepatic and renal impairment concurrently seek dose adjustment significantly. The long elimination t1/2 of ceftriaxone, approximately six to nine hours in adults and five to eighteen hours in children's less than one year and paediatrics, permits for once or twice daily dosing. Ceftriaxone is highly protein attached in human plasma (85% in healthy volunteers) and initially excreted by glomerular filtration, with a relatively long t1/2 (six hours) analogized with other β-lactam antibiotics (1 h). Very little of ceftriaxone appears in breast milk: breastfeeding children's less than one year would be exposed to less than one percent of the maternal dose on weight-adjusted basis, and little of this would be absorbed [4]. The percentage values of maximum plasma concentration, elimination $t1/_2$, plasma CL and Vd after a 50 mg/kg intravenous dose and after a 75 mg/kg intravenous dose in paediatric patients are suffering from bacterial infections. Ceftriaxone penetrated the inflamed meninges of children's less than one year and paediatric patients; CSF concentrations after a 50 mg/kg intravenous dose and after a 75 mg/kg IV dose [7]. The mean distribution volume of ceftriaxone ranges from 0.497 to 0.608 l/kg, and is not different in children's less than one month and children's less than one year [8, 9]. In children's less than one month, the total body Cl is 0.28 ml/min/kg after single administration and 0.41 to 0.54 ml/min/kg after

Journal of
Biomedical and Biological Sciences

Review Article Open Access

multiple ceftriaxone administrations. After single IM administration of ceftriaxone, the time to reach the peak plasma concentration is 1.8 hours [10].

Mechanism of Action: Ceftriaxone is a bactericidal agent that acts by suppression of bacterial cell wall secretion. Ceftriaxone has activity in the availability of certain beta-lactamases, both penicillinase and cephalosporins, of Gram-negative and Gram-positive bacteria. Ceftriaxone attaches to one or many of the penicillin-binding proteins which inhibits the final trans peptidoglycan step of peptidoglycan synthesis in bacterial cell wall, thus inhibiting biosynthesis and arresting cell wall assembly sequencing in bacterial cell death [11].

Spectrum of Activity: Ceftriaxone has bactericidal activity against most pathogens that commonly infect children, involving: Acinetobacter and Enterobacter species, haemophilus influenzae (enclosing beta-lactamase generating strains), *Klebsiella pneumoniae, Morganella, Neisseria and proteus species,* and *Serratia marcescens*. It possesses activity against consummate strains of S. aureus and S. pneumoniae, but *S. epidermidis*, MRSS, and *enterococcus faecalis* (Group D streptococci) are typically resistant. Ceftriaxone has meagre activity against anaerobes [12, 13].

Indications: Ceftriaxone is used mostly in hospital practice for neonatal sepsis, meningitis and ophthalmia neonatorum. Ceftriaxone is used for the management of neonatal sepsis and meningitis caused by susceptible gram (-ve) microorganisms (e.g., E. coli, P. aeruginosa, klebsiella, H. influenzae) and for the management of gonococcal infections. Ceftriaxone for injection, USP is revealed for the management of the pursuing infections when antecedent by vulnerable organisms: lower respiratory tract infections: antecedent by *S. pneumoniae, S. aureus, haemophilus influenzae, haemophilus parainfluenza, klebsiella pneumoniae, E. coli, Enterobacter aerogenes, proteus mirabilis* or *Serratia marcescens*; acute bacterial otitis media: antecedent by S. *pneumoniae, haemophilus influenzae* (involving beta-lactamase producing strains) or *Moraxella catarrhalis* (enclosing beta-lactamase producing strains); skin and skin structure infections: antecedent by *S. aureus, S. epidermidis, S. pyogenes*, viridians group streptococci, *E. coli, Enterobacter cloacae*; urinary tract infections (complicated and uncomplicated): antecedent by *E. coli, proteus mirabilis, proteus vulgaris, morganella morganii or klebsiella pneumoniae*, uncomplicated gonorrhoea (cervical/urethral and rectal): antecedent by *Neisseria gonorrhoeae*, involving both penicillinase- and non-penicillinase- producing strains, and pharyngeal gonorrhoea caused by non-penicillinase-producing strains of N. gonorrhoeae; pelvic inflammatory disease: antecedent by N. gonorrhoeae, bacterial septicemia: antecedent by *S. aureus, S. pneumoniae, E. coli, haemophilus influenzae* or *klebsiella pneumoniae*; bone and joint infections: caused by *S. aureus, S. pneumoniae, E. coli*; intra-abdominal infections: antecedent by *E. coli, klebsiella pneumoniae, Bacteroides fragilis*, clostridium species (Note: ultimate strains of clostridium difficile are resistant) or Pepto streptococcus species; meningitis: antecedent by *haemophilus influenzae, N. meningitidis or S. pneumoniae*. Ceftriaxone has also been used successfully in a limited number of cases of meningitis and shunt infection caused by *staphylococcus epidermidis* and *Escherichia coli* [14-21].

Adverse drug reaction: Ceftriaxone is well tolerated by most patients. As with other cephalosporins, the most common adverse effects associated with administrating ceftriaxone involve allergic reactions (rash, eosinophilia, fever, anaphylactoid shock, etc), local reactions can occur following IM and IV use, GI disturbances, and temporary escalate in transaminases, nephrotoxicity, pseudomembranous colitis, blood dyscrasias, haematological anomalies (granulocytopenia, thrombocytopenia, haemolytic anaemia), asymptomatic increase in blood urea nitrogen (BUN) values in 1 to 2% of patients to rare cases of AKF and gallbladder deliverance inadequacy [22-26]. High doses of ceftriaxone frequently cause a transient chelation to form in the biliary tract, and small asymptomatic renal stones sometimes form with sustained use. Certain side effects of ceftriaxone are illustrated beneath; Ceftriaxone-associated biliary adverse events in paediatrics are antecedent biliary pseudolithiasis and scarcely nephrolithiasis ordinarily

Journal of
Biomedical and Biological Sciences

Review Article Open Access

happens in children < 18 years who taking over doses of ceftriaxone [25]. Ceftriaxone is generally a safe drug, but it can have serious side effects. Kernicterus: The label warns of possible kernicterus since it can displace bilirubin from albumin [27, 28]. Antibiotic associated diarrhoea can also advance [29, 30]. Super infections: Prolonged therapy is associated with superficial colonization with inherited resistant bacteria. Therapy with ceftriaxone can sequence in infections with candida and non-susceptible bacteria like ESBL producers. Invasive candidiasis has become further often particularly among very LBW infants in neonatal ICUs. Third generation cephalosporin use is a specific risk factor for this condition. There is confirmation to indicate that management with third generation cephalosporins accelerates the pitfall of nosocomial infections with extended-spectrum β-lactamase (ESBL) generating E coli and Klebsiella in neonatal ICU [31]. Ceftriaxone has sometimes antecedent solemn neonatal erythroderma (red neonate syndrome) [32]. Ceftriaxone-associated renal adverse events in paediatrics are sequence in urolithiasis in children > 18 years, which could also antecedent acute kidney injury [33]. Ceftriaxone perhaps attaches with calcium containing products and figure insoluble chelation influencing to biliary pseudolithiasis [34]. Cholelithiasis, escalated biliary thickness, and pseudolithiasis seldom happen in period of being child, but there are two modes of distribution described by dual peaks, the 1st being at early stage of development and the 2nd in period of life when a paediatric advances into an adult [35, 36]. Ceftriaxone-associated haemolysis in paediatrics owing to the availability of a substance produced by the body to fight disease defends ceftriaxone, and the judgement displaced immune complex type lysis of red blood cells with liberation of haemoglobin [37]. Ceftriaxone displaces bilirubin from albumin attaching sites; ceftriaxone generated escalate of free bilirubin and erythrocyte-attached bilirubin and de-escalate of unconjugated bilirubin. Ceftriaxone reveals a substantial replacing consequence at accumulations gathered amid therapeutically used and should be used with precaution in more-peril jaundiced of a very young child [38]. Determination of free bilirubin, erythrocyte-attached bilirubin and unconjugated bilirubin was used to test the outcomes of ceftriaxone on the attaching of bilirubin to albumin [39].

Contraindication: Ceftriaxone contraindicated in preterm neonates and its contraindicated described in children's less than one month with jaundice, hypoalbuminemia, acidosis or impaired bilirubin binding. Hyperbilirubinemia is a significantly contraindicated for neonates administrated ceftriaxone, particularly premature neonates, because of the displacement of bilirubin from albumin-attaching sites and escalate in blood concentrations of free bilirubin. Ceftriaxone escalate pitfall agents for biliary pseudolithiasis involves age more than twenty-four months and high doses of ceftriaxone (2 g/day) used as a long-term management. A child < a month old and a child < twelve-month-old in special are at great pitfall of a meagre consequence because of bilirubin encephalopathy [40-44]. Ceftriaxone for parenteral is not given for patients with history of have cephalosporin category of antibiotics allergies. Coadministration of ceftriaxone and calcium containing solutions or products in a child < a month old is contraindicated: ceftriaxone reacts to calcium containing solution and it can chelate in lungs and kidneys of a child < twenty-eight days years and this could be life-threatening. Consequently, ceftriaxone is also contraindicated in a child < twenty-eight days years if they are anticipated to take any calcium-containing products. Coincident usage of IV ceftriaxone and calcium-containing solutions in neonates and young infants has been consociated with calcium chelation. Ceftriaxone is discordant with theophylline, azithromycin, calcium chloride (Cacl2), Ca gluconate, caspofungin, fluconazole, and vancomycin.

Drug interactions: Disulfiram-like reaction enclosing ceftriaxone in a child < eighteen years patient: Disulfiram-like reactions between ceftriaxone and ethanol have been well delineated in the literature. The reaction's mechanism encloses disulfiram or the falling medication obviating aldehyde dehydrogenase, the enzyme accountable for transforming acetaldehyde product of metabolism of ethanol to acetate. The sequencing of harmful is escalates in blood and

Journal of
Biomedical and Biological Sciences

Review Article Open Access

acetaldehyde influences to clinical outcomes that categorize in severity and that are commensurable to the quantum of being exposed to alcohol and the falling of medicine. Rare reactions are clearly shown as vasodilation sequencing in flushing and headache, while moderate to solemn reactions can advance from nausea and vomiting to hypotension, dysrhythmia, and death. Disulfiram-like reactions among ceftriaxone and ethanol are extremely infrequent. Coincident administrations of ceftriaxone with aminoglycosides such as gentamycin and loop diuretics (furosemide) perhaps escalate the peril of nephrotoxicity (hast degeneration in the kidney work owing to the toxic outcome of dual or triple medications). Coincident administrations of ceftriaxone with anticoagulant medications such as warfarin are associated with bleeding due to escalated prothrombin times, which is reversible with vitamin K.

Conclusion

Ceftriaxone is having many uses and useful "third-generation" cephalosporin that necessitates to be given every day. Ceftriaxone is actively worked on common gram positive and most gram-negative bacteria. Ceftriaxone has sometimes antecedent by solemn neonatal erythroderma (red infant syndrome). Ceftriaxone is not recommended for use in neonates with hyperbilirubinemia because ceftriaxone displaces bilirubin from albumin binding sites increasing unconjugated plasma concentration. Coadministration of ceftriaxone and calcium containing solutions or products in a child < a month old is contraindicated: ceftriaxone reacts to calcium containing solution and it can chelate in lungs and kidneys of a child < twenty-eight days years and this could be life-threatening.

Abbreviations

AKF: Acute renal failure; Ca2: Calcium; Cacl2: Calcium chloride; BUN: Blood urea nitrogen, CSF: Cerebrospinal fluid; ESBLs: Extended-spectrum β-lactamases; FDA: Food and drug administration; GI: Gastrointestinal; ICU: intensive care unit; IM: Intramuscular; IV: intravenous; MRSS: Methicillin-resistant strains of staphylococcus; USP: United States Pharmacopeia.

Acknowledgement

The author would be grateful to anonymous reviewers by the comments that increase the quality of this manuscript.

Data Sources: Sources searched include Google Scholar, Research Gate, PubMed, NCBI, NDSS, PMID, PMCID, EMBASE, Lancet, Science direct, Scielo, Scopus database and Cochrane database. Search terms involved: clinical pharmacology of ceftriaxone in paediatrics.

References

1. Tutunaru B, Samide A, Iordache S, Tigae C, Simionescu A, Popescu A. Ceftriaxone Degradation in the Presence of Sodium Halides Investigated by Electrochemical Methods Assisted by UV-Vis Spectrophotometry. Applied Sciences. 2021 Jan;11(4):1376.

2. Sacco O, Vaiano V, Rizzo L, Sannino D. Intensification of ceftriaxone degradation under UV and solar light irradiation in presence of phosphors based structured catalyst. Chemical Engineering and Processing-Process Intensification. 2019 Mar 1; 137:12-21.

3. Kordestani B, Yengejeh RJ, Takdastan A, Neisi AK. A new study on photocatalytic degradation of meropenem and ceftriaxone antibiotics based on sulfate radicals: Influential factors, biodegradability, mineralization approach. Microchemical Journal. 2019 May 1; 146:286-92.

4. Kaur B, Kuntus L, Tikker P, Kattel E, Trapido M, Dulova N. Photo-induced oxidation of ceftriaxone by persulfate in the presence of iron oxides. Science of the total environment. 2019 Aug 1; 676:165-75.

Journal of
Biomedical and Biological Sciences

Review Article Open Access

5. Badi MY, Azari A, Pasalari H, Esrafili A, Farzadkia M. Modification of activated carbon with magnetic Fe3O4 nanoparticle composite for removal of ceftriaxone from aquatic solutions. Journal of Molecular Liquids. 2018 Jul 1; 261:146-54.

6. Qiao J, Lv M, Qu Z, Zhang M, Cui X, Wang D, Piao C, Liu Z, Wang J, Song Y. Preparation of a novel Z-scheme KTaO3/FeVO4/Bi2O3 nanocomposite for efficient sonocatalytic degradation of ceftriaxone sodium. Science of The Total Environment. 2019 Nov 1; 689:178-92.

7. Zhao Y, Wang Y, Liang X, Shi H, Wang C, Fan J, Hu X, Liu E. Enhanced photocatalytic activity of Ag-CsPbBr3/CN composite for broad spectrum photocatalytic degradation of cephalosporin antibiotics 7-ACA. Applied Catalysis B: Environmental. 2019 Jun 15; 247:57-69.

8. Zhao Y, Wang Y, Shi H, Liu E, Fan J, Hu X. Enhanced photocatalytic activity of ZnSe QDs/g-C3N4 composite for Ceftriaxone sodium degradation under visible light. Materials Letters. 2018 Nov 15; 231:150-3.

9. Zhao Y, Liang X, Shi H, Wang Y, Ren Y, Liu E, Zhang X, Fan J, Hu X. Photocatalytic activity enhanced by synergistic effects of nano-silver and ZnSe quantum dots co-loaded with bulk g-C3N4 for Ceftriaxone sodium degradation in aquatic environment. Chemical Engineering Journal. 2018 Dec 1; 353:56-68.

10. Ainsworth SB. Neonatal formulary: drug use in pregnancy and the first year of life. John Wiley & Sons; 2014 Nov 10.

11. Hartman SJ, Upadhyay PJ, Hagedoorn NN, Mathôt RA, Moll HA, van der Flier M, Schreuder MF, Brüggemann RJ, Knibbe CA, de Wildt SN. Current Ceftriaxone Dose Recommendations are Adequate for Most Critically Ill Children: Results of a Population Pharmacokinetic Modeling and Simulation Study. Clinical pharmacokinetics. 2021 Oct;60(10):1361-72.

12. Lutsar I, Friedland IR. Pharmacokinetics and pharmacodynamics of cephalosporins in cerebrospinal fluid. Clinical pharmacokinetics. 2000 Nov;39(5):335-43.

13. Pacifici GM, Marchini G. Clinical pharmacology of ceftriaxone in neonates and infants: effects and pharmacokinetics. International Journal of Pediatrics. 2017 Sep 1;5(9):5751-78.

14. Lamb HM, Ormrod D, Scott LJ, Figgitt DP. Ceftriaxone. Drugs. 2002 May;62(7):1041-89.

15. Young TE, Mangum BN, Neofax A. A Manual of Drugs used in neonatal care. Antimicrobials. Edition 23rd. Thomson Reuters, Montvale. 2010; 7645:50-1.

16. Pacifici GM. Clinical pharmacology of ceftriaxone in infants and children. J Target Drug Deliv. 2019;3(1):1-3.

17. Wayne PA. Clinical and Laboratory Standards Institute: Performance standards for antimicrobial susceptibility testing: 20th informational supplement. CLSI document M100-S20. 2010.

18. Biek D, Critchley IA, Riccobene TA, Thye DA. Ceftaroline fosamil: a novel broad-spectrum cephalosporin with expanded anti-Gram-positive activity. Journal of antimicrobial chemotherapy. 2010 Nov 1;65(suppl_4): iv9-16.

19. Karlowsky JA, Adam HJ, DeCorby MR, Lagacé-Wiens PR, Hoban DJ, Zhanel GG. In vitro activity of ceftaroline against gram-positive and gram-negative pathogens isolated from patients in Canadian hospitals in 2009. Antimicrobial agents and chemotherapy. 2011 Jun;55(6):2837-46.

Journal of
Biomedical and Biological Sciences

Review Article Open Access

20. Baddour LM, Wilson WR, Bayer AS, Fowler Jr VG, Bolger AF, Levison ME, Ferrieri P, Gerber MA, Tani LY, Gewitz MH, Tong DC. Infective endocarditis: diagnosis, antimicrobial therapy, and management of complications: a statement for healthcare professionals from the Committee on Rheumatic Fever, Endocarditis, and Kawasaki Disease, Council on Cardiovascular Disease in the Young, and the Councils on Clinical Cardiology, Stroke, and Cardiovascular Surgery and Anesthesia, American Heart Association: endorsed by the Infectious Diseases Society of America. Circulation. 2005 Jun 14;111(23): e394-434.

21. Huang X, Qu Y, Cid CA, Finke C, Hoffmann MR, Lim K, Jiang SC. Electrochemical disinfection of toilet wastewater using wastewater electrolysis cell. Water Research. 2016 Apr 1; 92:164-72.

22. Gökçe S, Yıldırım M, Erdoğan D. A retrospective review of children with gallstone: Single-center experience from Central Anatolia. Turk J Gastroenterol. 2014 Feb 1;25(1):46-53.

23. Biner B, Öner N, Çeltik C, Bostancioğlu M, Tunçbilek N, Güzel A, Karasalihoğlu S. Ceftriaxone-associated biliary pseudolithiasis in children. Journal of Clinical Ultrasound. 2006 Jun;34(5):217-22.

24. Zhao Y, Wang Y, Liu E, Fan J, Hu X. Bi2WO6 nanoflowers: an efficient visible light photocatalytic activity for ceftriaxone sodium degradation. Applied Surface Science. 2018 Apr 1; 436:854-64.

25. Jayasankar B, Karan K. O2 electrochemistry on Pt: A unified multi-step model for oxygen reduction and oxide growth. Electrochimica Acta. 2018 May 20; 273:367-78.

26. Chapman RL. Prevention and treatment of Candida infections in neonates. InSeminars in perinatology 2007 Feb 1 (Vol. 31, No. 1, pp. 39-46). WB Saunders.

27. Shen X, Liu W, Fang X, Jia J, Lin H, Xu M, Geng H. Acute kidney injury caused by ceftriaxone-induced urolithiasis in children: a single-institutional experience in diagnosis, treatment and follow-up. International urology and nephrology. 2014 Oct;46(10):1909-14.

28. Avci Z, Koktener A, Uras N, Catal F, Karadag A, Tekin O, Degirmencioglu H, Baskin E. Nephrolithiasis associated with ceftriaxone therapy: a prospective study in 51 children. Archives of disease in childhood. 2004 Nov 1;89(11):1069-72.

29. Gökçe S, Yıldırım M, Erdoğan D. A retrospective review of children with gallstone: Single-center experience from Central Anatolia. Turk J Gastroenterol. 2014 Feb 1;25(1):46-53.

30. ALE HM, Sotoudeh K, NASOUHI S, Salamati P, AKHTAR KH. Ceftriaxone induced biliary pseudolithiasis in children: report of 14 cases.

31. Citak A, Garratty G, Ücsel R, Karabocuoglu M, Uzel N. Ceftriaxone-induced haemolytic anaemia in a child with no immune deficiency or haematological disease. Journal of paediatrics and child health. 2002 Apr;38(2):209-10.

32. Gulian JM, Dalmasso C, Pontier F, Gonard V. Displacement effect of ceftriaxone on bilirubin bound to human serum albumin. Chemotherapy. 1986;32(5):399-403.

33. MM AT, Ghithan J, Abu-Taha MI, Darwish SM, Abu-Hadid MM. Spectroscopic approach of the interaction study of ceftriaxone and human serum albumin. Journal of Biophysics and Structural Biology. 2014 Feb 28;6(1):1-2.

34. Schaad UB, Tschäppeler H, Lentze MJ. Transient formation of precipitations in the gallbladder associated with ceftriaxone therapy. The Pediatric Infectious Disease Journal. 1986 Nov 1;5(6):708-9.

Journal of
Biomedical and Biological Sciences

Review Article Open Access

35. Zindel LR, Kranzler HR. Pharmacotherapy of alcohol use disorders: seventy-five years of progress. Journal of Studies on Alcohol and Drugs, Supplement. 2014 Mar(s17):79-88.

36. Dong H, Zhang J, Ren L, Liu Q, Zhu S. Unexpected death due to cefuroxime-induced disulfiram-like reaction. Indian Journal of Pharmacology. 2013 Jul;45(4):399.

37. Cina SJ, Russell RA, Conradi SE. Sudden death due to metronidazole/ethanol interaction. The American journal of forensic medicine and pathology. 1996 Dec 1;17(4):343-6.

38. Zareh M, Davis A, Henderson S. Reversal of warfarin-induced hemorrhage in the emergency department. Western Journal of Emergency Medicine. 2011 Nov;12(4):386.

39. da Trindade MT, Salgado HR. A critical review of analytical methods for determination of ceftriaxone sodium. Critical Reviews in Analytical Chemistry. 2018 Mar 4;48(2):95-101.

40. Samide A, Tutunaru B, Cioateră N, Vladu AC, Spinu C, Tigae C. Catalytic activity of thallium on electrochemical degradation of Metronidazole from aqueous solutions. Chemical Engineering Communications. 2016 Dec 1;203(12):1572-81.

41. Zheng J, Yan K, Wu Z, Liu M, Wang Z. Effective removal of sulfanilic acid from water using a low-pressure electrochemical RuO2-TiO2@ Ti/PVDF composite membrane. Frontiers in chemistry. 2018:395.

42. Consortti LP, Salgado HR. A critical review of analytical methods for quantification of Cefotaxime. Critical Reviews in Analytical Chemistry. 2017 Jul 4;47(4):359-71.

43. de Marco BA, Salgado HR. Characteristics, properties and analytical methods of cefadroxil: a review. Critical Reviews in Analytical Chemistry. 2017 Mar 4;47(2):93-8.

44. Ribeiro AR, Schmidt TC. Determination of acid dissociation constants (pKa) of cephalosporin antibiotics: Computational and experimental approaches. Chemosphere. 2017 Feb 1; 169:524-33.