aziTHROMYCIN

Newborn use only

2022

Alert	Azithromycin in the newborn period increases the risk of developing pyloric stenosis.[21,22]
Indication	1. *Bordetella pertussis* – post-exposure prophylaxis and treatment 2. Neonatal *Chlamydia trachomatis* conjunctivitis and pneumonia 3. *Chlamydia trachomatis* and *Mycoplasma pneumoniae* pneumonia >3 months of age 4. Eradication of *Ureaplasma urealyticum* in preterm infants 5. Prevention of bronchopulmonary dysplasia (BPD) in preterm neonates – routine use is not recommended
Action	Azithromycin inhibits protein synthesis by attaching to the 50S subunit of the bacterial ribosome in susceptible organisms. It exhibits bacteriostatic activity with higher potency than erythromycin against *Ureaplasma urealyticum* isolates in vitro. Azithromycin inhibits neutrophil influx and chemoattractant/cytokine release in murine lung non-infectious, as well as pneumonia, injury models. It is preferentially concentrated in pulmonary epithelial lining fluid and alveolar macrophages.[21]
Drug Type	Macrolide antibiotic (subclass Azalide)
Trade Name	Azith, Azithromycin Alphapharm, Azithromycin-AFT, Zithromax
Presentation	Oral: 200 mg/5 mL (15 mL) suspension, 500 mg tablet IV: 500 mg vial
Dosage	**<u>*Bordetella pertussis* (post-exposure prophylaxis or treatment)</u>** 10 mg/kg/dose daily orally or IV[2] for 5 days. **<u>Treatment of neonatal *Chlamydia trachomatis* conjunctivitis and pneumonitis</u>** 20 mg/kg/dose daily orally for 3 days. **<u>Eradication of *Ureaplasma urealyticum* in preterm infants</u>** 20 mg/kg/dose daily IV for 3 days. **<u>Pneumonia due to *Chlamydia trachomatis* or *Mycoplasma pneumoniae* >3 months of age</u>** Initial therapy or therapy for serious infection: 10 mg/kg/dose **IV** once a day on days 1 and 2, followed by oral therapy if needed. Step-down or Mild therapy: 10 mg/kg **ORALLY** on day 1, followed by 5 mg/kg once daily on days 2–5.
Dose adjustment	Therapeutic hypothermia – Limited evidence. ECMO- Limited evidence. Renal impairment – Caution advised if creatinine clearance < 10 (AUC increased by 35%). Hepatic impairment – Limited evidence.
Route	Oral IV
Maximum Daily Dose	20 mg/kg
Preparation	**Oral** Manufacturer's recommendations should guide reconstitution of the oral suspension as multiple of brands of azithromycin are available. **IV** Add 4.8 mL of water for injection to the vial to make a concentration of 100 mg/mL solution. Shake until dissolved. Add 1 mL of reconstituted solution to 49 mL of sodium chloride 0.9% to make a concentration of 2 mg/mL and infuse over 1–3 hours. Maximum concentration for infusion is 2 mg/mL.
Administration	**Oral:** Shake well before use. May be given with or without feed. **IV:** Infuse over at least 1 hour.
Monitoring	During infusion – heart rate and blood pressure. IV site for signs of phlebitis. Liver function.
Contraindications	Hepatic dysfunction with prior azithromycin therapy. Concomitant therapy with QT interval prolonging drugs (e.g. cisapride).
Precautions	Hepatic dysfunction.

	IV solutions of a concentration greater than 2 mg/mL may cause local infusion-site reactions.
Drug Interactions	Drugs that can prolong QT interval. Digoxin – may result in digoxin toxicity.
Adverse Reactions	Common: Nausea, vomiting, abdominal pain and diarrhoea (all less than erythromycin). Rare: Hypertrophic pyloric stenosis, thrombophlebitis (after IV administration), ventricular dysrhythmias (after IV administration). In general, the risk of dysrhythmias is increased when these agents are administered in combination with other drugs that prolong the QT interval. Increased liver enzymes, hepatitis, hepatic necrosis, hypersensitivity reactions.
Compatibility	Fluids: Glucose 5%, glucose 5% in sodium chloride solutions, Hartmann's, sodium chloride 0.9%, sodium chloride 0.45%. Y-site: Aciclovir, adrenaline (epinephrine), amphotericin (liposomal), ampicillin, argipressin (vasopressin), calcium chloride, calcium gluconate, cefazolin, dexamethasone, dexmedetomidine, digoxin, dobutamine, dopamine, fluconazole, ganciclovir, heparin, hydrocortisone, isoproterenol (isoprenaline), labetalol, lidocaine, linezolid, magnesium sulfate, mannitol, meropenem, methylprednisolone, metronidazole, milrinone, naloxone, octreotide, pancuronium, phenobarbital, sodium acetate, sodium bicarbonate, sodium phosphates, tigecycline, vancomycin, vecuronium.
Incompatibility	Fluids: No information. Drugs: Amikacin, amiodarone, aztreonam, cefotaxime, ceftazidime, ceftriaxone, chlorpromazine, ciprofloxacin, clindamycin, fentanyl, furosemide (frusemide), gentamicin, imipenem-cilastatin, ketorolac, midazolam, morphine sulfate, mycophenolate mofetil, pentamidine, piperacillin-tazobactam (EDTA-free), potassium chloride, thiopental sodium, ticarcillin-clavulanate, tobramycin.
Stability	Oral suspension: After reconstitution, the suspension should be stored below 30°C and any remaining suspension discarded after 10 days. Reconstituted IV solution: Stable for 24 hours at ≤30°C.
Storage	Oral: Store below 30°C. IV: Alphapharm, Azith - Store below 25°C. Protect from light. IV: AFT, Zithromax - Store below 30°C.
Excipients	IV brands: Azith, Alphapharm, AFT, Zithromax: citric acid, sodium hydroxide. Zithromax powder for oral suspension: sucrose, tribasic sodium phosphate, hyprolose, xanthan gum, Spray Dried Artificial Cherry 11929, Spray Dried Artificial Banana 15223 and Crema Vaniglia N11489 Polvere SC613737.
Special Comments	
Evidence	**Efficacy** ***Bordetella pertussis* – post-exposure prophylaxis and treatment** Systematic review of eradicating *B. pertussis* from the nasopharynx found short-term antibiotics (azithromycin for three to five days, or clarithromycin or erythromycin for seven days) were as effective as long-term (erythromycin for 10 to 14 days) (risk ratio (RR) 1.01; 95% CI 0.98 to 1.04), but had fewer side effects (RR 0.66; 95% CI 0.52 to 0.83). Effective treatment regimens included 3 days azithromycin (10 mg/kg as a single dose) (2 trials); and 5 days azithromycin (10 mg/kg on the first day and 5 mg/kg once daily on day two to five) (2 trials). [1] The Centers for Disease Control and Prevention recommend oral azithromycin as the preferred agent for post-exposure prophylaxis (PEP) and treatment in infants younger than 1 month of age.[2] Azithromycin has the advantage of once daily dosing and shorter duration of therapy. In infants 1 month of age and older, CDC recommends erythromycin, clarithromycin and azithromycin as preferred agents for the treatment of pertussis. For infants 2 months of age and older, an alternative to macrolides is trimethoprim-sulfamethoxazole. Recommended azithromycin dose for both treatment and PEP is the same for infants <6 months of age: 10 mg/kg/day once a day for 5 days (only limited safety data are available). [2,3] **Treatment of *Chlamydia trachomatis* conjunctivitis and pneumonia** *C. trachomatis* infection in neonates is most frequently recognised by conjunctivitis that develops 5–12 days after birth. *C. trachomatis* also can cause a subacute, afebrile pneumonia with onset at ages 1–3 months. There are limited data on the efficacy of azithromycin regimens in newborns. Hammerschlag 1998 reported oral azithromycin 20 mg/kg/day single dose resulted in 2 of 5 treatment failures and oral azithromycin 20 mg/kg/day single dose for 3 days resulted in 1 of 6 treatment failures.[4] However,

azithromycin has been extensively trialled for eradication of *C. trachomatis* in populations including infants and children.[5, 6, 7] Use of azithromycin for prevention of bronchopulmonary dysplasia provides some safety data in premature infants (see below).

Recommendation: The Centers for Disease Control and Prevention (CDC) recommend oral erythromycin 50 mg/kg per day given orally in four divided doses for 14 days for either chlamydial conjunctivitis or pneumonia. An alternative regimen is azithromycin 20 mg/kg/day once daily for 3 days. Topical antibiotic therapy alone is inadequate and is unnecessary when systemic treatment is administered. [8,9]

***Congenital Mycoplasma pneumoniae pneumonia* in neonates**

Mycoplasma species are common inhabitants of female genital tract and there are case reports of congenital mycoplasma pneumonia in neonates. [10, 11] Azithromycin in varying dosage schedule has been used for management in these reports.[10, 11] *Mycoplasma genitalium* is susceptible to azithromycin. *Mycoplasma hominis* is intrinsically resistant to azithromycin and other macrolides, but it is susceptible to the lincosamide and Lincomycin. However, Lincomycin is not recommended for use in neonates.

Pneumonia due to *Chlamydia trachomatis* or *Mycoplasma pneumoniae* in infants >3 months of age

A systematic review of antibiotics for community-acquired lower respiratory tract infections secondary to *Mycoplasma pneumoniae* in children found no difference in clinical response between children randomised to a macrolide antibiotic and children randomised to a non-macrolide antibiotic for infants in whom a diagnosis of mycoplasma or chlamydia pneumonia was not made. In one controlled study of children with recurrent respiratory infections, whose acute LRTI was associated with *Mycoplasma*, *Chlamydia* or both, by polymerase chain reaction and/or paired sera, 100% of children treated with azithromycin had clinical resolution of their illness compared to 77% not treated with azithromycin at one month.[12]

Recommendation of the Pediatric Infectious Diseases Society and the Infectious Diseases Society of America: Parenteral: Intravenous azithromycin 10 mg/kg on days 1 and 2 of therapy; transition to oral therapy if possible. Enteral: Azithromycin 10 mg/kg on day 1, followed by 5 mg/kg/day once daily on days 2–5.[13]

Prevention of bronchopulmonary dysplasia in preterm infants

Nair et al conducted a systematic review of azithromycin and other macrolides on the incidence of bronchopulmonary dysplasia (BPD) in preterm infants. Macrolides when used prophylactically, did not show significant reduction in BPD (risk ratio, RR, 0.88, 95% CI, 0.75–1.03), death (RR 0.89, 95% CI 0.79–1.01) or in the composite outcome of BPD/death.[14] Similarly, there was no significant reduction in BPD (RR 0.64, 95% CI 0.31–1.31) or the composite outcome of BPD/death (RR 0.41, 95% CI 0.05–3.13), when macrolides were used in *Ureaplasma*-positive infants. However, prophylactic azithromycin therapy (3 studies) was associated with significant reduction in BPD (RR 0.83, 95% CI 0.71–0.97; number needed to treat, 10) and of BPD or death (RR 0.86, 95% CI 0.77–0.97; NNT 10). Dose regimens were 10 mg/kg/day for 7 days (2 studies) and 10 mg/kg/day for 7 days followed by 5 mg/kg/day for further 7 days (one study). In a recent meta-analysis of three RCTs, Razak and Alshehri found significant reduction in the combined outcome of BPD or death (RR, 0.83; 95% CI, 0.70, 0.99) in *Ureaplasma –positive* infants who received Azithromycin.[15]

Conclusion: Although prophylactic azithromycin therapy was associated with a reduction in BPD and BPD/death in preterm infants, there is limited information on pharmacokinetics and potential harmful effects. Further high quality RCTs should be done before routine use of azithromycin in the neonatal population. [14, 15]

Eradication of *Ureaplasma urealyticum* in preterm infants

A 3-day course of 20 mg/kg/day IV azithromycin commencing treatment within 72 hours of life in 24–28 weeks GA infants showed efficacy in eradicating *Ureaplasma spp.* from the preterm respiratory tract. [16] All post-treatment cultures were negative. Side effects reported in this study were related to prematurity. Similarly, Visacardi reported eradication of *Ureaplasma in* all *azithromycin* group infants (n= 19) compared to 16% placebo group infants.[17]

Other infections

There are case reports of azithromycin use in congenital *Toxoplasma Gondi* and *Campylobacter Jejuni* infections.[18,19]

Bioavailability

Bioavailability of oral azithromycin is 38%.[20]

Safety

	Most common adverse events of azithromycin are gastrointestinal. Infantile hypertrophic pyloric stenosis (IHPS) while uncommon, is the most serious reported adverse event. Eberly et al reviewed 2466 children who developed IHPS.[21] Azithromycin exposure in the first 14 days had an odds ratio (OR) of 8.26 and, at 15–42 days, an OR of 2.98. No association was identified between day 43 and day 90. A systematic review of 11 articles involving 473 neonates found no significant difference in the incidence of elevated liver enzymes between the azithromycin and placebo group and reported 4 cases of infantile hypertrophic pyloric stenosis (<1%). [22] A recent systematic review did not find significant difference in the prolongation QT interval amongst children receiving azithromycin or placebo.[23] However, higher doses of azithromycin were associated with higher incidence of prolonged QT. **Pharmacokinetics** Preterm neonates have reduced azithromycin clearance and increased volume of distribution compared to older children. The estimated half-life is approximately 58 hours for a typical 1 kg neonate. Once administered, very little of azithromycin resides in the plasma and the vast majority of azithromycin accumulates intracellularly leading to a prolonged elimination $t_{1/2}$ and extended mean residence time (MRT). These characteristics favour administering higher dosage regimens of azithromycin. For effective *Ureaplasma urealyticum* eradication, the plasma concentration of free unbound azithromycin must be maintained above the minimum inhibitory concentration that is required to inhibit 50% (MIC_{50}) of *Ureaplasma urealyticum*. Multiple dose administration of 10 mg/kg/day for 3 days azithromycin is inadequate to maintain azithromycin plasma concentrations above the MIC_{50}. On the other hand, a dosage regimen of 20 mg/kg/day for 3 days would be sufficient to maintain azithromycin plasma concentration above the MIC_{50}.[24] Azithromycin (AZM) in fine granules was studied by Tajima T, et al 1997, for its pharmacokinetics and clinical efficacy in eight child patients with ages between 1 month and 8 years. AZM was administered to the patients once a day at a dose of 10 mg/kg for 3 days. The clinical efficacy of AZM in 8 patients with microbial infections (pneumonia in one, *Mycoplasma pneumoniae* in two, acute tonsillitis in one, *Bordetella pertussis* in one, *Campylobacter* spp. enteritis in one, infectious enteritis in one, *Salmonella* enteritis in one) were evaluated as "excellent" in five cases, "good" in two and "not evaluable" in one. As for the microbial efficacy, isolated strains were eradicated in 2 out of 3 patients. No adverse reaction was found except for one case with abnormal laboratory change, a mildly increased ALT value. Plasma samples were collected from 3 cases. The elimination half-life of AZM was 45.8 hours. $AUC_{0-\infty}$was 12.6 microgram.h/mL. Urine sample was collected from one. AZM concentration in urine was 35.0 microgram/mL during a period between 48 and 72 hours after the start of treatment.[24,25]
Practice points	
References	1. Altunaiji SM, Kukuruzovic RH, Curtis NC, Massie J. Antibiotics for whooping cough (pertussis). Cochrane Database Syst Rev [serial on the Internet]. 2007. 2. Centers for Disease Control and Prevention. Recommended Antimicrobial Agents for the Treatment and Postexposure Prophylaxis of Pertussis, 2005. MMWR Recomm Rep. 2005 December 9, 2005 / 54(RR14); 1-16. 3. American Academy of Pediatrics. Pertussis (whooping cough). In: Red Book: 2021-2024 Report of the Committee on Infectious Diseases, 32nd ed, Kimberlin DW, Barnett ED, Lynfield R, Sawyer MH (Eds), American Academy of Pediatrics, 2021. p.578. 4. Hammerschlag MR, Gelling M, Roblin PM, Kutlin A, Jule JE. Treatment of neonatal chlamydial conjunctivitis with azithromycin. Pediatr Infect Dis J. 1998; 17:1049-50. 5. Bailey RL, Arullendran P, Whittle HC, Mabey DC. Randomised controlled trial of single-dose azithromycin in treatment of trachoma. Lancet. 1993; 342:453-6. 6. Gebre T, Ayele B, Zerihun M, Genet A, Stoller NE, Zhou Z, House JI, Yu SN, Ray KJ, Emerson PM, Keenan JD, Porco TC, Lietman TM, Gaynor BD. Comparison of annual versus twice-yearly mass azithromycin treatment for hyperendemic trachoma in Ethiopia: a cluster-randomised trial. Lancet. 2012; 379:143-51. 7. Harding-Esch EM, Sillah A, Edwards T, Burr SE, Hart JD, Joof H, Laye M, Makalo P, Manjang A, Molina S, Sarr-Sissoho I, Quinn TC, Lietman T, Holland MJ, Mabey D, West SK, Bailey R, Partnership for Rapid Elimination of Trachoma study g. Mass treatment with azithromycin for trachoma: when is one round enough? Results from the PRET Trial in the Gambia. [Erratum appears in PLoS Negl Trop Dis.

2013 Jun; 7(6). doi:10.1371/annotation/0bae8b34-5ae7-4044-a071-8d88d520a01b]. PLoS Negl Trop Dis. 2013; 7:e2115.
8. American Academy of Pediatrics (AAP). In: Pickering LK, Baker CJ, Kimberlin DW, Long SS, eds. Red Book: 2012 Report of the Committee on Infectious Diseases. 29th ed. Elk Grove Village, IL: American Academy of Pediatrics; 2012.
9. American Academy of Pediatrics. Chlamydia trachomatis. In: Red Book: 2021-2024 Report of the Committee on Infectious Diseases, 32nd Ed, Kimberlin DW, Barnett ED, Lynfield R, Sawyer MH (Eds), Red Book: 2021-2024 Report of the Committee on Infectious Diseases, Itasca, IL 2021.
10. Samonini A, Grosse C, Aschero A, Boubred F, Ligi I. Congenital Pneumonia Owing to Mycoplasma pneumoniae. J Pediatr. 2018 Dec;203:460-460
11. Srinivasjois RM, Kohan R, Keil AD, Smith NM. Congenital Mycoplasma pneumoniae pneumonia in a neonate. Pediatr Infect Dis J. 2008 May; 27(5):474-5.
12. Gardiner SJ, Gavranich JB, Chang AB. Antibiotics for community-acquired lower respiratory tract infections secondary to Mycoplasma pneumoniae in children. Cochrane Database Syst Rev. 2015; 1:CD004875.
13. Bradley JS, Byington CL, Shah SS, Alverson B, Carter ER, Harrison C, Kaplan SL, Mace SE, McCracken Jr GH, Moore MR, St Peter SD. The management of community-acquired pneumonia in infants and children older than 3 months of age: clinical practice guidelines by the Pediatric Infectious Diseases Society and the Infectious Diseases Society of America. Clinical infectious diseases. 2011; 53(7):e25-76.
14. Nair V, Loganathan P, Soraisham AS. Azithromycin and other macrolides for prevention of bronchopulmonary dysplasia: a systematic review and meta-analysis. Neonatology. 2014; 106(4):337-47.
15. Razak A, Alshehri N. Azithromycin for preventing bronchopulmonary dysplasia in preterm infants: A systematic review and meta-analysis. Pediatr Pulmonol. 2021 May; 56(5):957-966.
16. Merchan LM, Hassan HE, Terrin ML, Waites KB, Kaufman DA, Ambalavanan N, Donohue P, Dulkerian SJ, Schelonka R, Magder LS, Shukla S. Pharmacokinetics, microbial response, and pulmonary outcomes of multidose intravenous azithromycin in preterm infants at risk for Ureaplasma respiratory colonization. Antimicrobial agents and chemotherapy. 2015; 59(1):570-8.
17. Viscardi RM, Terrin ML, Magder LS, et al. Randomised trial of azithromycin to eradicate Ureaplasma in preterm infants. Arch Dis Child Fetal Neonatal Ed. 2020 Nov;105(6):615-622
18. Li J, Zhao J, Yang X, Wen Y, Huang L, Ma D, Shi J. One severe case of congenital toxoplasmosis in China with good response to azithromycin. BMC Infect Dis. 2021 Sep 6; 21(1):920.
19. Hirschel J, Herzog D, Kaczala GW. Rectal Bleeding in Neonates due to Campylobacter Enteritis: Report of 2 Cases with a Review of the Literature. Clin Pediatr (Phila). 2018 Mar;57(3):344-347
20. MerativeTM Micromedex® Complete IV Compatibility (electronic version). Merative, Ann Arbor, Michigan, USA. Available at: https://www.micromedexsolutions.com/ (cited: 19th June 2018).
21. Eberly MD, Eide MB, Thompson JL, Nylund CM. Azithromycin in early infancy and pyloric stenosis. Pediatrics. 2015; 135(3):483-8.
22. Smith C, Egunsola O, Choonara I, et al. Use and safety of azithromycin in neonates: a systematic review. BMJ Open. 2015; 5:e008194.
23. Zeng L, Xu P, Choonara I, Bo Z, Pan X, et al. Safety of azithromycin in pediatrics: a systematic review and meta-analysis. Eur J Clin Pharmacol. 2020 Dec; 76(12):1709-1721.
24. Hassan HE, Othman AA, Eddington ND, Duffy L, Xiao L, Waites KB, Kaufman DA, Fairchild KD, Viscardi RM. Pharmacokinetics, safety, and biologic effects of azithromycin in extremely preterm infants at risk for ureaplasma colonization and bronchopulmonary dysplasia. The Journal of Clinical Pharmacology 2011; 51(9):1264-75.
25. Tajima T, Kobayashi M, Abe T, Fujii R. Pharmacokinetic, bacteriological and clinical studies on azithromycin in children. The Japanese journal of antibiotics. 1997 Feb; 50(2):200-5.

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Authors Contribution

Original author/s	Chris Wake, Srinivas Bolisetty
Revision author/s	Nilkant Phad
Expert review	Tony Lai, Brendan McMullan, Alison Kesson, Pamela Palasanthiran
Evidence Review	David Osborn
Nursing Review	Eszter Jozsa, Priya Govindaswamy, Sarah Neale
Pharmacy Review	Carmen Burman, Michelle Jenkins
ANMF Group contributors	Srinivas Bolisetty, Bhavesh Mehta, John Sinn, Mohammad Irfan Azeem, Simarjit Kaur, Michelle Jenkins, Carmen Burman, Helen Huynh
Final editing	Thao Tran
Electronic version	Cindy Chen, Ian Callander
Facilitator	Srinivas Bolisetty