Drugs in Renal Failure

I. DOSE ADJUSTMENT METHODS

A. Maintenance Dose

In patients with renal insufficiency, the dose may be adjusted using the following methods:

1. Interval extension (I): Lengthen the intervals between individual doses, keeping the dose size normal. For this method, the suggested interval is shown

2. Dose reduction (D): Reduce the amount of individual doses, keeping the interval between the doses normal. This method is particularly recommended for drugs in which a relatively constant blood level is desired. For this method, the percentage of the usual dose is shown

3. Interval extension and dose reduction (DI): Lengthen the interval and reduce the dose

4. Interval extension or dose reduction (D, I): In some instances, either the dose or the interval can be changed

NOTE: These dose adjustments are for beyond the neonatal period.

For neonatal renal dosing please consult a neonatal dosage reference.

These dose modifications are only approximations. Each patient must be monitored closely for signs of drug toxicity, and serum levels must be measured when available. Drug dose and interval should be adjusted accordingly. When in doubt please consult a nephrologist or pharmacist with a specialty in renal dosing.

B. Dialysis

Quantitative effects of hemodialysis (He) and peritoneal dialysis (P) on drug removal are shown. Y indicates the need for a supplemental dose with dialysis. The supplemental dose may not be a full dose, but instead a lower than standard dose. N indicates no need for adjustment. The designation No does not preclude the use of dialysis or hemoperfusion for drug overdose. ? indicates insufficient data available. Please consult with a nephrologist or pharmacist who is very familiar with renal dosing in dialysis.

II. RENAL FUNCION TESTS

A. Tests of Glomerular Function

Creatinine clearance (Ccr):

a. Timed urine specimen: Standard measure of glomerular filtration rate (GFR); closely approximates inulin clearance in the normal range of GFR. When GFR is low, Ccr is greater than inulin clearance. Usually inaccurate in children with obstructive uropathy or problems with bladder emptying.

$$\text{Ccr (mL/min/1.73 m}^2\text{)} = (U\times [V/P]) \times 1.73/BSA$$

where U (mg/dL) = urinary creatinine concentration; V (mL/min) = total urine volume (mL) divided by the duration of the collection (min) (24 hours = 1440 min); P (mg/dL) = serum creatinine concentration (may average two levels) and BSA (m2) = body surface area

b. Estimated GFR from plasma creatinine: Useful when a timed specimen cannot be collected; reasonable estimate of GFR for children with relatively normal renal function and body habitus, although does tend to overestimate GFR. If habitus is markedly abnormal or precise measurement of GFR is needed, more standard methods of measuring GFR must be used

$$\text{Estimated GFR (mL/min/1.73 m}^2\text{)} = kL/Pcr$$

where k = proportionality constant; L = height (cm); Pcr = plasma creatinine (mg/dL)

PROPORTIONALITY CONSTANT FOR CALCULATING GLOMERULAR FILTRATION RATE

Age	*k* Values
Low birth weight during first year of life	0.33
Term AGA during first year of life	0.45
Children and adolescent girls	0.55
Adolescent boys	0.70

AGA, Appropriate for gestational age.

From Schwartz GJ, Brion LP, Spitzer A: The use of plasma creatinine concentration for estimating glomerular filtration rate in infants, children, and adolescents. Pediatr Clin North Am 1987;34:571.

NORMAL VALUES OF GLOMERULAR FILTRATION RATE

Age	GFR (Mean) (mL/min/1.73 m^2)	Range (mL/min/1.73 m^2)
Neonates <34 wk gestational age		
2–8 days	11	11–15
4–28 days	20	15–28
30–90 days	50	40–65
Neonates >34 wk gestational age		
2–8 days	39	17–60
4–28 days	47	26–68
30–90 days	58	30–86
1–6 mo	77	39–114
6–12 mo	103	49–157
12–19 mo	127	62–191
2 yr–adult	127	89–165

From Holliday MA, Barratt TM: Pediatric nephrology. Baltimore, Williams & Wilkins, 1994, p. 1306.

ANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE[1–4]

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Acyclovir (IV)	Renal	2–4	q8hr	D,I	25–50	NI	q12hr	Y (He)
					10–25	NI	q24hr	N (P)
					<10	50% ↓	q24hr	
Amantadine†	Renal	10–28	q12–24hr	D,I	30–50	50% ↓	q24hr	N (He)[α]
					15–29	50% ↓	q48	N (P)
					<15	NI daily dose	q7 days	
Amikacin	Renal	1.5–3	q8–12hr	I	Loading dose 5–7.5 mg/kg; subsequent doses are best determined by serum levels and assessment of renal insufficiency.[1]			Y (He) Y (P)
Amoxicillin‡	Renal	0.7–2	q8–12hr	I	10–30	NI	q12hr	Y (He)
					<10	NI	q24hr	? (P)
Amoxicillin/ clavulanate‡	Renal	1	q8–12hr	I	10–30	NI	q12hr	Y (He)
					<10	NI	q24hr	? (P)

*Route in parentheses indicates secondary route of excretion.

†In adults; guidelines not established in children.

[α]On day one normal dose should be given then decreased for subsequent doses based on renal insufficiency.

‡Should not use 875-mg tablet or extended release tablets in patients with CrCl <30 mL/min.

ANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Amphotericin B	Renal (40% over 7 days)	Initial 15–48 hr Terminal 15 days	q24hr	D,I	Dosage adjustments are unnecessary with preexisting renal impairment; "if decreased renal function is due to amphotericin B, daily dose can be decreased by 50% or dose given every other day. Therapy may be held until serum creatinine begins to decline. Can give 1–4 mg/L of peritoneal dialysis fluid ± low-dose IV therapy."[1]			N (He) ? (P)
Amphotericin B lipid complex (Abelcet)	Renal (1%)	173	q24hr	I	Renal toxicity is dose dependent. No firm guidelines for dose adjustments.			N (He) ? (P)
Amphotericin B, liposomal (AmBisome)	Renal (≤10%)	100–153	q24hr	I	No guidelines established.			N (He) ? (P)
Ampicillin†	Renal	1–1.8	q6–12hr	I	10–30 <10	NI NI	q6–12hr q12hr	Y (He) ? (P)
Ampicillin/ sulbactam	Renal	1–1.8	q4–8hr	I	15–29 <15	NI NI	q12hr q24hr	Y (He) ? (P)
Aztreonam	Renal (hepatic)	1.3–2.2	q6–12hr	D	10–30 <10	50% ↓ 75% ↓	NI NI	Y (He) Y (P)
Cefaclor	Renal	0.5–1	q8–12hr	D	<10	50% ↓	NI	Y (He) ? (P)
Cefadroxil	Renal	1–2	q12–24hr	I	10–25 <10	NI NI	q24hr q36hr	? (He) ? (P)

Cefazolin	Renal	1.5–2.5	q6–8hr	D,I	40–70 20–40 <20	40%↓[Σ] 75%↓[Σ] 90%↓[Σ]	q12hr q12hr q12hr	Y (He) ? (P)
Cefdinir	Renal	1.1–2.3	q12–24hr	D,I	<30	7 mg/kg/dose (children; max 300 mg) 300 mg (adults)	q24hr q24hr	Y (He)[Ω] ? (P)
Cefepime[†]	Renal	1.8–2	q8–12hr	I	10–50 <10	NI NI	q24hr q48hr	Y (He) ? (P)
Cefixime	Renal (hepatic)	3–4	q12–24hr	D	21–60 <20	25% ↓ 50% ↓	NI NI	Y (He) ? (P)
Cefotaxime	Renal	1–1.5	q6–12hr	D	<20	50% ↓	NI	Y (He) ? (P)
Cefotetan	Renal (hepatic)	3.5	q12hr	I	10–30 <10	NI NI	q24hr q48hr	Y (He) ? (P)
Cefoxitin	Renal	0.75–1.5	q4–8hr	I	30–50 10–30 <10	NI NI NI	q8–12hr q12–24hr q24–48hr	Y (He) ? (P)
Cefpodoxime	Renal	2.2	q12hr	I	<30	NI	q24hr	Y (He)[§] ? (P)

*Route in parentheses indicates secondary route of excretion.

[†]In adults; guidelines not established in children.

[Σ]After initial loading dose is administered then decrease dose based on renal insufficiency.

[Ω]Patients on hemodialysis should have a dose of 300 mg or 7 mg/kg/dose at the conclusion of each hemodialysis session with subsequent doses q48hr.

[§]For patients on hemodialysis, administer 3 times per week.

ANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Cefprozil	Renal	1.3	q12–24hr	D	<30	50% ↓	NI	Y (He) ? (P)
Ceftazidime	Renal	1–2	q8–12hr	I	30–50 10–30 <10	NI NI NI	q12hr q24hr q24–48hr	Y (He) ? (P)
Ceftibuten	Renal	1.9–3	q24hr	D	30–49 5–29	50% ↓ 75% ↓	NI NI	Y (He)[αα] ? (P)
Ceftizoxime	Renal	1.6	q6–12hr	I	50–80 10–50 <10	NI NI NI	q8–12hr q36–48hr q48–72hr	Y (He) ? (P)
Cefuroxime (IV)	Renal	1–2	q8–12hr	I	10–20 <10	NI NI	q12hr q24hr	Y (He) ? (P)
Cephalexin	Renal	0.5–2.5	q6–8hr	I	10–40 <10	NI NI	q8–12hr q12–24hr	Y (He) ? (P)
Cephradine	Renal	0.7–2	q6–12hr	D,I	10–50 <10 *OR* 25–50 10–25 <10	50% ↓ 75% ↓ NI NI NI	NI NI q12hr q24hr q36hr	? (He) ? (P)
Ciprofloxacin[†]	Renal (hepatic)	3–5	q8–12hr	D,I	<30 (IV) 30–50 (PO) <30 (PO)	200–400 mg[†] 250–500 mg[†] 250–500 mg[†]	q18–24hr q12hr q18hr	Y (He) ? (P)

Clarithromycin	Renal/hepatic	3–9	q12hr	D,I	<30	50% ↓	q12–24hr	? (He) ? (P)
Ertapenem†	Renal	2.5–4	q12–24hr	D	≤30	50% ↓	NI	Y (He) ? (P)
Erythromycin	Hepatic (renal)	1.5–2	q6–12hr	D	<10	25%–50%	↓NI	N (He) N (P)
Ethambutol	Renal (hepatic)	2.5–3.6	q24hr	I	10–50 <10	NI NI or reduced	q24–36hr q48hr	Y (He) ? (P)
Famciclovir†	Renal (hepatic)	2–3	q8hr	D,I	**Herpes Zoster Treatment†,*** **			Y (He)
					40–59	500 mg	q12hr	? (P)
					20–39	500 mg	q24hr	
					<20	250 mg	q24hr	
					Recurrent Genital Herpes Treatment†,* **			
					40–59	500 mg	q12hr × 1 day	
					20–39	500 mg	Single dose	
					<20	250 mg	Single dose	
					Recurrent Genital Herpes Suppression†,ΣΣ			
					>40	250 mg	q12hr	
					20–39	125 mg	q12hr	
					<20	125 mg	q24hr	

*Route in parentheses indicates secondary route of excretion.

†In adults; guidelines not established in children.

ααWith hemodialysis administer 9 mg/kg (max dose 400 mg) after hemodialysis.

***Patients on hemodialysis administer 250 mg after each dialysis session.

ΣΣPatients on hemodialysis administer 125 mg after each dialysis session.

ANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Famciclovir—cont'd					**Recurrent Herpes Labialis—Single Dose Regimen**[†,***]			
					>60	1,500 mg as single dose		
					40–59	750 mg as single dose		
					20–39	500 mg as single dose		
					<20	250 mg as single dose		
					Recurrent Orolabial or Genital Herpes in HIV-Infected Patients[†,***]			
					40–59	500 mg	q12hr	
					20–39	500 mg	q12hr	
					<20	250 mg	q24hr	
Fluconazole[†]	Renal	15.2–30	q24hr	D	≤50	50% ↓	NI	Y (He)[ΣΣΣ] ? (P)
Flucytosine	Renal	2.5–7.4	q6hr	I	20–40	NI	q12hr	Y (He)
					10–20	NI	q24hr	? (P)
					<10	NI	q24–48hr	
Foscamet	Renal	2–4.5	Induct: q8hr Maint: q24hr	D	See package insert for adjustments for induction and maintenance.			? (He) ? (P)
Ganciclovir	Renal	2.5–3.6	Induct: q12hr IV Maint: q24hr IV PO	D,I	**Induction IV**			Y (He)[§] N (P)
					50–69	2.5 mg/kg	q12hr	
					25–49	2.5 mg/kg	q24hr	
					10–24	1.25 mg/kg	q24hr	

			OR q8hr		<10	1.25 mg/kg	3 times/wk after He	
					Maintenance IV			
					50–69	2.5 mg/kg	q24hr	
					25–49	1.25 mg/kg	q24hr	
					10–24	0.625 mg/kg	q24hr	
					<10	0.625 mg/kg	3 times/wk after He	
					Maintenance PO[†]			
					50–69	1,500 mg	q24hr	
						OR 500 mg	q8hr	
					25–49	1,000 mg	q24hr	
						OR 500 mg	q12hr	
					10–24	500 mg	q24hr	
					<10	500 mg	3 times/wk after He	
Gentamicin	Renal	0.5–5	q8–24hr	I	40–60	NI	q12hr	Y (He)
					20–40	NI	q24hr	Y (P)[¶]
					<20	NI	Monitor levels	

*Route in parentheses indicates secondary route of excretion.

[†]In adults; guidelines not established in children.

***Patients on hemodialysis administer 250 mg after each dialysis session.

ΣΣΣPatients on hemodialysis: administer 100% of recommended dose after each dialysis session.

[§]For patients on hemodialysis, administer 3 times per week.

[¶]May add to peritoneal dialysate to obtain adequate serum levels.

ANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Imipenem/cilastatin	Renal	1–1.4	q6–8hr	D,I	41–70 mL/min/1.73 m^2	50% ↓ in max daily dose	q6hr	Y (He) ? (P)
					21–40 mL/min/1.73 m^2	63% ↓ in max daily dose	q8hr	
					6–20 mL/min/1.73 m^2	75% ↓ in max daily dose	q12hr	
					≤5 mL/min/1.73 m^2	Should not receive imipenem unless on He		
Isoniazid	Renal (hepatic)	2–5 (slow)# 0.5–1.5 (fast)	q24hr	D	<10	100%	NI	Y (He) ? (P)
Kanamycin	Renal	1.8–5	q8hr	D,I	GFR > 50 mL/min	10%–40% ↓	q12hr	Y (He) Y (P)
					GFR 10–50 mL/min	30%–70% ↓	q12–18hr	
					GFR < 10 mL/min	70%–80% ↓	q24–48hr	

Lamivudine[†,**]	Renal	1.4–7	q12hr	D,I	30–49	Nl	q24hr	N (He)
					15–29	First dose 100%, then 66%	q24hr	N (P)
					5–14	First dose 100%, then 33%	q24hr	
					<5	First dose 33%, then 17%	q24hr	
Levofloxacin[†]	Renal (hepatic)	6–8	q12–24hr	D,I	**500 mg q24hr Regimen**			N (He)
					20–49	First dose 500 mg, then 250 mg	q24hr	N (P)
					10–19	First dose 250–500 mg, then 250 mg	q48hr	
					750 mg q24hr Regimen			
					20–49	750 mg	q48hr	
					10–19	500 mg	q48hr	
					250 mg q24hr Regimen			
					10–19	250 mg	q48hr	

*Route in parentheses indicates secondary route of excretion.

[†]In adults; guidelines not established in children.

[#]Rate of acetylation of isoniazid.

**GFR ≥5 mL/min: Give full dose as first dose; GFR <5 mL/min: Give 33% of full dose as first dose.

ANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Loracarbef	Renal	0.78–1	q12hr	D, I	10–49	50% ↓	NI	Y (P)
					OR	NI	q24hr	? (P)
					<10	NI	q3–5 days	
Meropenem	Renal	1–1.5	q8hr	D,I	26–50	NI	q12hr	Y (He)
					10–25	50% ↓	q12hr	? (P)
					<10	50% ↓	q24hr	
Metronidazole	Hepatic (renal)	6–12	q6–8hr	D	<10	50% ↓	NI	Y (He)
								Y (P)
Norfloxacin	Hepatic (renal)	2–4	q12hr	I	10–50	NI	q12–24hr	N (He)
					<10	NI	q24hr	N (P)
Oseltamivir†	Renal	1–10	q12–24hr	I	**Treatment of Influenza**			? (He)
					10–30	75 mg	q24hr	? (P)
					<10	No recommended dosage regimen.		
					Prophylaxis of Influenza			
					10–30	75 mg	q48hr	
					<10	No recommended dosage regimen.		

Oxacillin	Renal (hepatic)	0.3–1.8	q4–12hr	D	<10	Use lower range of usual dose.	NI	N (He) N (P)
Penicillin G–and aqueous K^+ Na^+ (IV)	Renal (hepatic)	0.5–1.2	q4–6hr	I	10–30 <10	NI NI	q8–12hr q12–18hr	Y (He) ? (P)
Penicillin V K^+ (PO)	Renal (hepatic)	30–40 min	q6–8hr	I	<10	NI	q8hr	Y (He) ? (P)
Pentamidine	Renal	6.4–9.4	q24hr	I	10–30 <10	NI NI	q36hr q48hr	N (He) N (P)
Piperacillin	Renal (hepatic)	0.5–1	q4–6hr	I	20–40 <20	NI NI	q8hr q12hr	Y (He) ? (P)
Piperacillin/ tazobactam	Renal	Piperacillin: 0.5–1 Tazobactam: 0.7–1.6	q6–8hr	D,I	20–40 <20	30% ↓ 30% ↓	q6hr q8hr	Y (He) Y (P)
Rifabutin†	Renal (hepatic)	16–69	q12–24hr	D	<30	50% ↓	NI	? (He) ? (P)
Rifampin	Hepatic (renal)	3–4	q12–24hr	D	10–50 <10	NI NI	NI NI	N (He) N (P)
Streptomycin sulfate	Renal	2–10	q24hr	D,I	50–80 10–50 <10	7.5 mg/kg 7.5 mg/kg 7.5 mg/kg	q24hr q24–72hr q72–96hr	? (He) ? (P)

*Route in parentheses indicates secondary route of excretion.

†In adults; guidelines not established in children.

ANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Sulfamethoxazole/ trimethoprim (cotrimoxazole)	Sulfamethoxazole: Hepatic (renal) Trimethoprim: Renal (hepatic)	Sulfamethoxazole: 9–12 Trimethoprim: 6–11	q12hr	D	15–30 <15	50% ↓ Not recommended	NI	? (He) ? (P)
Sulfisoxazole	Renal	4–8	q6hr	I	10–50 <10	NI NI	q8–12hr q12–24hr	Y (He) ? (P)
Tetracycline	Renal (hepatic)	6–12	q6hr	I	50–80 10–50 <10	NI NI NI	q8–12hr q12–24hr q24hr	Y (He) ? (P)
Ticarcillin††	Renal	0.9–1.3	q4–6hr IV	I	10–30 <10	NI NI	q8hr q12hr	Y (He) ? (P)
Ticarcillin/ clavulanate††	Renal	Ticarcillin: 0.9–1.3 Clavulanate: 1–1.5	q4–6hr	I	10–30 <10 <10 *AND* hepatic impairment	NI NI NI	q8hr q12hr q24hr	Y (He) ? (P)
Tobramycin‖	Renal	0.5–5	q6–8hr	I	Any degree of renal insufficiency	2.5 mg/kg; Subsequent doses determined by levels		Y (He) Y (P)¶

Valacyclovir†	88% as acyclovir in urine	Valacyclovir: ~30 min Acyclovir: 2–3	q12–24hr	D,I	**Herpes Zoster (Adults)**			Y (He) ? (P)
					30–49	1 g	q12hr	
					10–29	1 g	q24hr	
					<10	500 mg	q24hr	
					Genital Herpes (Adol/Adults): Initial Episode			
					10–29	1 g	q24hr	
					<10	500 mg	q24hr	
					Genital Herpes (Adol/Adults): Recurrent Episode			
					<10	500 mg	q24hr	
					Genital Herpes (Adol/Adults): Suppressive			
					<10	500 mg	q24hr (for usual dose of 1 g q24hr)	
						OR 500 mg	q48hr (for usual dose of 500 mg q24hr)	

*Route in parentheses indicates secondary route of excretion.

†In adults; guidelines not established in children.

‖Subsequent doses best determined by measurement of serum levels and assessment of renal insufficiency.

¶May add to peritoneal dialysate to obtain adequate serum levels.

††May inactivate aminoglycosides in patients with renal impairment.

ANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Valacyclovir—cont'd					**Herpes Labialis (Adol/Adults)**			
					30–49	1 g	q12hr × 2 doses	
					10–29	500 mg	q12hr × 2 doses	
					<10	500 mg	Single dose	
Valganciclovir (see ganciclovir)								
Vancomycin‖	Renal	2.2–8	q6–12hr	I	>90	Nl	q6hr	N (He)††
					70–89	Nl	q8hr	N (P)
					46–69	Nl	q12hr	
					30–45	Nl	q18hr	
					15–29	Nl	q24hr	
					<15	10–20 mg/kg	Subsequent doses best determined by levels.	

*Route in parentheses indicates secondary route of excretion.

‖Subsequent doses best determined by measurement of serum levels and assessment of renal insufficiency.

††May inactivate aminoglycosides in patients with renal impairment.

CrCl, Creatinine clearance; GFR, glomerular filtration rate; He, hemodialysis; Induct, induction; K+, potassium; Maint, maintenance; Na+, sodium; Nl, normal; P, peritoneal dialysis; $t_{1/2}$ half-life with normal renal function.

NONANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE[1–4]

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Acetaminophen	Hepatic	2–4	q4–6hr	I	10–50	NI	q6hr	N (He)
					<10	NI	q8hr	N (P)
Acetazolamide	Renal	2.4–5.8	q6–24hr	I	10–50	NI	q12hr	Y (He)
					<10	Avoid use		? (P)
Allopurinol	Renal	1–3	q6–12hr	D	10–50	50% ↓	NI	? (He)
					<10	70% ↓	NI	? (P)
Aminocaproic Acid	Renal	1–2	q4–6hr	D	Oliguria/ESRD	75% ↓	NI	? (He)
								? (P)
Aspirin†	Hepatic (renal)	3–10	q4hr	I	10–50	NI	q4–6hr	Y (He)
					<10	Avoid use		N (P)
Atenolol	Renal (GI)	3.5–7	q24hr	D, I	15–35	1 mg/kg *OR* 50 mg	q24hr	Y (He)
					<15	1 mg/kg *OR* 50 mg	q48hr	N (P)
Azathioprine‡	Hepatic (renal)	0.7–3	q24hr	D	10–50	25% ↓	NI	Y (He)
					<10	50% ↓	NI	? (P)
Bismuth subsalicylate	Hepatic (renal)	Salicylate: 2–5 Bismuth: 21–72 days	q3–4hr	D	Avoid use in patients with renal failure			NA

*Route in parentheses indicates secondary route of excretion.

†With large doses, the $t_{1/2}$ is prolonged up to 30 hr.

‡Azathioprine rapidly converted to mercaptopurine ($t_{1/2}$ = 0.5–4 hr).

NONANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Calcium supplements	GI	Variable	Variable		<25	May require dosage adjustment depending on calcium level		
Captopril	Renal (hepatic)	1–12.5	q6–24hr	D	10–50	25% ↓	NI	Y (He)
					<10	50% ↓	NI	N (P)
Carbamazepine	Hepatic (renal)	Initial: 25–65 Subsequent: 8–17	q6–24hr	D	<10	25% ↓ (monitor serum levels)	NI	? (He) ? (P)
Cetirizine	Renal (hepatic)	6.2–9	q12–24hr	D	**<6 yr with Renal Impairment**			? (He)
					Use not recommended			? (P)
					6–11 yr			
					Any degree of Insufficiency	<2.5 mg	q24hr	
					≥12 yr			
					11–30	15 mg	q24hr	
					<11	Use not recommended		
Chloral hydrate	Renal	8–11	q6–8hr	NA	<50	Avoid use		NA
Chloroquine	Renal (hepatic)	3–5 days	q6hr–7 days	D	<10	50% ↓	NI	N (He) N (P)
Chlorothiazide	Renal	0.75–2	q12–24hr	NA	<30	May be ineffective Use not recommended		NA

Cimetidine	Renal (hepatic)	1.4–2	q6–12hr	D, I	>40	NI	q6hr	Y (He)
					20–40	NI	q8hr	? (P)
						OR 25% ↓	NI	
					<20	NI	q12hr	
						OR 50% ↓	NI	
Codeine	Hepatic (renal)	2.5–3.5	q4–6hr	D	10–50	25% ↓	NI	? (He)
					<10	50% ↓	NI	? (P)
Desloratadine	Renal (GI)	27	q24hr	I	Any degree of renal impairment	NI	q48hr	? (He)
								? (P)
Digoxin[§]	Renal	18–48	q12–24hr	D, I	**Digitalizing Dose**			N (He)
					ESRD	50% ↓	NA	N (P)
					Maintenance Dose			
					10–50	25%–75% ↓	NI	
						OR NI	q36hr	
					<10	75%–90% ↓	NI	
						OR NI	q48hr	
Diphenhydramine	Hepatic	2–8	q6–8hr	I	10–50	NI	q6–8hr	? (He)
					<10	NI	q6–8hr	? (P)
Disopyramide[‖]	Renal (GI)	3.15–10	q6hr	I	30–40	NI	q8hr	? (He)
					15–30	NI	q12hr	? (P)
					<15	NI	q24hr	
EDTA calcium chloride[‖]	Renal	1.5 (IM)	q4hr IM	D, I	**Serum Creatinine: IV Dose**			? (He)
		0.3 (IV)	q12hr IV		≤2 mg/dL	1 g/m^2	q24hr × 5 days	? (P)
					2–3 mg/dL	500 mg/m^2	q24hr × 5 days	
					3–4 mg/dL	500 mg/m^2	q48hr × 3 doses	
					>4 mg/dL	500 mg/m	Once weekly	

*Route in parentheses indicates secondary route of excretion. [‖]Guidelines in adults; guidelines not established in children.

[§]Decrease loading dose by 50% in end-stage renal disease because of decreased volume of distribution.

NONANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Enalapril (IV: Enalaprilat)	Renal (hepatic)	1.3–6.3 (PO) 5.1–38 (IV)	q6–24hr	D	10–50 <10	0%–25% ↓ 50% ↓	NI NI	? (He) N (P)
				Use not recommended in infants and children ≤16 yr with GFR <30 mL/min/1.73m^2				
Enoxaparin[‖,¶]	Renal	4.5–7	q12hr	I	<30	NI	q24hr	? (He) ? (P)
Famotidine	Renal	0.8–5	q8–12hr	D, I	10–50 <10	50% ↓ OR NI NI	NI q24hr q36–48hr	? (He) ? (P)
Felbamate[‖]	Renal	20–30	q6–8hr	D	Any degree of renal impairment	50% ↓	NI	? (He) ? (P)
Fentanyl	Renal (hepatic)	2–4	q30min–1hr	D	10–50 <10	25% ↓ 50% ↓	NI NI	NA
Fexofenadine	GI (renal)	14–18	q14–18hr	I	Any degree of renal impairment	NI	q24hr	? (He) ? (P)
Flecainide	Renal/hepatic	8–27	q8–12hr	D	<20	25%–50%↓	NI	N (He) N (P)
Furosemide	Renal (hepatic)	0.5	q6–24hr PO q6–12hr IV		Avoid use in oliguric states			N (He) N (P)
Gabapentin[‖]	Renal (hepatic)	4.7–9	q8hr	D, I	30–59 15–29 <15	200–700 mg 200–700 mg 100–300 mg	q12hr q24hr q24hr	Y (He) N (P)

Hydralazine[#]	Hepatic (renal)	2–8	q4–6hr (IV) q6–12hr (PO)	I	10–50 <10	NI NI	q8hr(fast acetylator) q8–16hr q12–24hr (slow acetylator)	? (He) ? (P)
Insulin (regular)**	Hepatic (renal)	1.5	Variable	D	10–50 <10	25% ↓ 50%–75% ↓	NI NI	N (He) N (P)
Levetiracetam[‖]	Renal	5–8	q12hr	D	**Children** <50 **Adults** 50–80 30–50 <30 ESRD on dialysis	 50% ↓ 500–1,000 mg 250–750 mg 250–500 mg 500–1,000 mg	 NI NI NI NI q24hr	Y (He) N (P)
Lisinopril	Renal	11–13	q24hr	D	10–30 <10 Use not recommended for children with CrCl <30 mL/min/1.73m^2	50% ↓ 75% ↓	NI NI	Y (He) N (P)
Lithium	Renal	18–24	q6–8hr	D	10–50 <10	25%–50% ↓ 50%–75% ↓	NI NI	Y (He) N (P)
Loratadine	Renal/hepatic	Loratadine: 8.4 Metabolite: 28	q24hr	I	<30	NI	q48hr	? (He) ? (P)

*Route in parentheses indicates secondary route of excretion.

[‖]Guidelines in adults; guidelines not established in children.

[¶]Monitor antifactor Xa closely.

[#]Dose interval varies for rapid and slow acetylators with normal and impaired renal function.

**Renal failure may cause hyposensitivity or hypersensitivity to insulin; adjust to clinical response and blood glucose.

NONANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Meperidine	Renal (hepatic) Normeperidine: Renal	2.3–4	q3–4hr	D	10–50 <10	25% ↓ 50% ↓	NI NI	? (He) ? (P)
Methadone	Hepatic (renal)	4–87	q3–12hr	D	<10	25%–50% ↓	NI	N (He) N (P)
Methyldopa	Hepatic (renal)	1–3	q6–12hr PO q6–8hr IV	I	>50 10–50 <10	NI NI NI	q8hr q8–12hr q12–24hr	Y (He) ? (P)
Metoclopramide	Renal	2.5–6	q6hr PO q6–8hr IV	D	40–50 10–40 <10	25% ↓ 50% ↓ 50%–75%↓	NI NI NI	? (He) ? (P)
Midazolam	Hepatic (renal)	2.2–6.8	Variable	D	10–29 <10	25% ↓ 50% ↓	NI NI	NA
Milrinone	Renal	1.5–3.8	Continuous infusion	D	50 mL/min/1.73 m^2 40 mL/min/1.73 m^2 30 mL/min/1.73 m^2 20 mL/min/1.73 m^2 10 mL/min/1.73 m^2 5 mL/min/1.73m^2		0.43 mcg/kg/min 0.38 mcg/kg/min 0.33 mcg/kg/min 0.28 mcg/kg/min 0.23 mcg/kg/min 0.2 mcg/kg/min	NA
Morphine	Hepatic (renal)	1–67.8	Variable	D	10–50 <10	25% ↓ 50% ↓	NI NI	? (He) ? (P)
Neostigmine	Hepatic (renal)	0.5–2.1	Variable	D	10–50 <10	50% ↓ 75% ↓	NI NI	? (He) ? (P)

Oxcarbazepine	Renal	Oxcarbazepine: 2 MHD: 9	q12hr	D	<30	50% ↓ in initial dose and slower titration	NI	? (He) ? (P)
Pancuronium bromide	Renal (hepatic)	1.8	q30–60min OR continuous infusion	D	10–50 <10	50% ↓ Avoid use	NI	? (He) ? (P)
Phenazopyridine	Renal (hepatic)	?	q8hr for2 days	I	50–80 <50	NI Avoid use	q8–16hr	NA
Phenobarbital	Hepatic (renal, 30%)	37–140	q8–12hr	I	<10	NI	q24hr	Y (He) Y (P)
Primidone	Hepatic (renal, 20%)	Primidone: 10–12 Metabolite: 16	q6–12hr	I	>50 10–50 <10	NI NI NI	q12hr q12–24hr q24hr	Y (He) ? (P)
Procainamide	Hepatic (renal)	Procainamide: 1.7–4. 7 NAPA: 6–8	q3–6hr PO q4–6hr IM	I	**Oral** 10–50 <10 **IV (Adult) Maintenance** 10–50 <10 **IV (Adult) Loading Dose** Severe renal 12 mg/kg impairment	 NI NI 33% ↓ 67% ↓ NA	 q6–12hr q8–24hr NI NI NA	Y (He) N (P)
Quinidine	Renal	2.5–8	q4–12hr	D	<10	25% ↓	NI	Y (He) N (P)

*Route in parentheses indicates secondary route of excretion.

NONANTIMICROBIALS REQUIRING ADJUSTMENT IN RENAL FAILURE (Continued)

	Pharmacokinetics			Adjustments in Renal Failure				
Drug	Route of Excretion*	Normal $t_{1/2}$ (hr)	Normal Dose Interval	Method	CrCl (mL/min)	Dose	Interval	Supplemental Dose for Dialysis
Ranitidine	Renal (hepatic)	1.8–2.5	q12hr PO q6–8hr IV/IM	D	10–50 <10	50% ↓ 75% ↓	NI NI	N (He)†† ? (P)
Spironolactone	Renal (hepatic)	Spironolactone: ↓ 1.3–1.4 Canrenone: 13–24	q6–24hr	I	10–50 <10	NI Avoid use	q12–24hr	NA
Terbutaline (IV/PO)	Renal (hepatic)	2.9–14	Variable	D	<50	NI	NI	? (He) ? (P)
Thiopental	Hepatic (renal)	3–11.5	One-time dose	D	<10	25% ↓	NI	NA
Triamterene	Hepatic (renal)	1.6–2.5	q12–24hr	I	>50 <50	NI Avoid use	q12hr	NA
Verapamil	Renal (hepatic)	2–8	Variable	D	<10 Use caution and closely monitor ECG for PR prolongation, BP and other signs of overdose	NI	NI	N (He) N (P)
Vigabatrin (Sabril)	Renal	5–8	q12hr	D	50–80 30–50 10–30	25% ↓ 50% ↓ 75% ↓	NI NI NI	? (He) ? (P)

*Route in parentheses indicates secondary route of excretion.

††Adjust dose schedule to administer dose at the end of dialysis.

BP, Blood pressure; CrCl, creatinine clearance; ECG, electrocardiogram; ESRD, end-stage renal disease; GFR, glomerular filtration rate; GI, gastrointestinal; He, hemodialysis; IV, intravenous; MDH, 10-monohydroxy metabolite; NA, not applicable; maint, maintenance dose; P, peritoneal dialysis; PO, per os (by mouth).