Drug Dosing in Renal Failure

George R. Aronoff

Introduction

Uremia affects every organ system in the body. Since the kidney is the major regulator of the internal fluid environment, the physiological changes associated with renal disease have pronounced effects on the pharmacology of many drugs. Clinicians must consider changes in the absorption, distribution, metabolism, and excretion of drugs and their active or toxic metabolites when treating patients with impaired renal function. Renal diseases are often superimposed on underlying problems, such as hypertension, diabetes mellitus (DM), and heart disease. These co-morbidities compound the complexity of management.

The number of patients with impaired renal function has increased. Improvements in the management of patients with chronic diseases that decrease renal function have expanded the numbers of patients with impaired renal function, because they live longer. Advanced age, DM, and coronary artery disease (CAD) are no longer barriers to chronic renal replacement strategies. In addition, renal function decreases with age, and older patients make up the most rapidly growing patient group for which special understanding of drug disposition is important.

New dialysis membranes and devices, acceptance of intermittent and continuous peritoneal dialysis, and the application of continuous extracorporeal renal replacement therapies (RRT) contribute to the need for detailed understanding of drug transport across biological and artificial membranes. Physicians caring for these patients must understand the biochemical and physiologic effects of uremia on drug disposition and the effects of dialysis on drug and metabolite removal. This chapter provides a rational schema of pharmacotherapy for patients with decreased renal function and for those on dialysis.

Patient Assessment

Appropriate pharmacotherapy for patients with kidney disease begins with a careful history and physical examination. Previous medications, concurrent medicines, and drug-related allergy or toxicity are important in the initial evaluation of patients with impaired renal function. Preventing potential drug interactions before choosing a drug regimen reduces adverse drug effects. For example, dialysis patients average > 8 concurrent medications and suffer 3 times the incidence of adverse drug events as patients with normal renal function [1, 2].

Establishing specific diagnoses before initiating drug therapy permits clinicians to avoid polypharmacy and decreases the chances of untoward drug interactions. Individualizing therapy allows one drug to treat several con-

ditions. For example, an angiotensin converting enzyme (ACE) inhibitor used to lower blood pressure in a hypertensive patient can also improve heart failure and slow the progression of diabetic glomerulosclerosis.

The extracellular fluid volume determines the distribution volume of many drugs. Edema or ascites increases the volume of distribution of water-soluble drugs, while dehydration contracts this volume. Determination of an appropriate loading dose requires an assessment of hydration status.

Similarly, accurate drug dosing requires measurements of body height and weight. Ideal body weight (IBW) can be a guide for dosing obese patients. For men, IBW is 50 kg plus 2.3 kg for each inch (2.54 cm) over 5 feet (152 cm). For women, IBW is 45.5 kg plus 2.3 kg for each inch (2.54 cm) over 5 feet (152 cm). Many clinicians use the average of the measured body weight and the ideal body weight as the value on which to base drug doses [3].

Functional impairment of other excretory organs influences drug therapy in patients with renal disease by limiting alternative pathways for drug and metabolite elimination. Finding the stigmata of liver disease is a strong indication of the need to further decrease drug doses in patients with renal impairment.

Measurement of Renal Function

The rate and extent of drug and metabolite elimination by the kidneys is proportional to the glomerular filtration rate (GFR). Although the serum creatinine measurement is frequently used to establish renal function, this measurement also reflects muscle mass. Serum creatinine measurements within the normal range will not accurately estimate renal function in elderly or debilitated patients. In such patients, the use of standard drug doses may result in serious overdose and toxic drug or metabolite accumulation.

The Cockroft and Gault equation, shown below, relates the serum creatinine measurement to the patients age, body mass, and gender.

$$C_{cr} = \frac{(140 - age) \times (IBW)}{72 \times S_{cr}} \times (0.85 \text{if female})$$

C_{cr} = Creatinine Clearance (mL/min)
S_{cr} = Serum Creatinine (mg/dL)

For obese men and women the equation should be modified:

$$C_{cr}(\text{obesemen}) = \frac{(137 - age) \times \left[(0.285 \times wt) + (12.1 \times ht^2)\right]}{51 \times S_{cr}}$$

$$C_{cr}(\text{obesewomen}) = \frac{(146 - age) \times \left[(0.287 \times wt) + (9.74 \times ht^2)\right]}{60 \times S_{cr}}$$

wt = patient's weight in kg
ht = patient's height in cm

When renal function is unstable, the serum creatinine does not reflect the clearance rate. A timed urine collection, using the midpoint serum creatinine measurement, estimates renal function when the serum creatinine is changing. Oliguric patients usually have a creatinine clearance < 5 mL/min.

Dialysis patients may have residual renal function that contributes to the elimination of drugs and their metabolites. Residual renal function decreases over time but depends on the level of renal function present at the initiation of RRT and the underlying renal disease.

Serum creatinine measurements alone should not be used to estimate intrinsic renal function in dialysis patients. Estimating residual renal function in nonoliguric dialysis patients is difficult, because the serum creatinine reflects the adequacy of dialysis and muscle mass, as well as residual glomerular filtration. Since creatinine clearance measurements do not accurately estimate the GFR in patients with renal failure requiring dialysis, the determination of renal function requires measurement of the plasma clearance rate of radioisotopes.

Medications may interfere with laboratory measurements of renal function. Drugs can falsely increase or decrease the measurement of serum creatinine concentration, urea nitrogen (BUN), and uric acid, and alter urine color or urine protein concentration.

Effects of Uremia on Drug Disposition

Bioavailability

Drug bioavailability is the amount of a drug that enters the central circulation and the rate at which it appears in the blood. Intravenous (IV) drugs enter the central circulation directly. They have a rapid onset of action. Other routes of administration require that the drugs cross a series of biological membranes and pass through organs that may eliminate some of the drug before it reaches the site of action. Only a fraction of the dose reaches the systemic circulation. The measurement of bioavailability is expressed as the percentage of the dose that reaches the systemic venous circulation. The time required to achieve the maximum concentration of the drug in venous blood reflects the rate of drug absorption.

The rate and extent of gastrointestinal (GI) absorption are important considerations for oral drugs. GI membranes act as a barrier to drug absorption, and the presence of metabolizing enzymes in GI epithelium decreases drug absorption.

Orally administered drugs are first absorbed into the portal circulation. Since these drugs first pass through the liver, bioavailability depends on the extent of hepatic metabolism.

Uremia decreases GI drug absorption. Nausea, vomiting, and gastroparesis are common in uremia, but little specific information about bowel function is available in patients with renal failure. Salivary urea concentrations increase when urea accumulates in the plasma. Gastric urease forms ammonia from swallowed urea. The ammonia buffers gastric acid in uremic patients. The liver regenerates urea from the reabsorbed ammonia as it passes through the portal circulation. This urea-ammonia cycle increases gastric pH and decreases the absorption of drugs that need acid hydrolysis for absorption [4].

Ferrous iron salts require hydrolysis to their ferric form by gastric acid for absorption and are not well absorbed by dialysis patients because of impaired acid hydrolysis in the stomach. In addition, the dissolution of many tablet dosage forms requires the acid environment normally found in the stomach. Absorption of these products is incomplete and occurs more slowly in an alkaline environment.

Patients with renal impairment often ingest large quantities of antacids to bind dietary phosphate. Chelation and the formation of nonabsorbable complexes with multivalent cations frequently used in antacids decrease the bioavailability of some drugs [5]. This effect is particularly important on the absorption of some antibiotics and digoxin.

Craig and colleagues demonstrated impaired GI absorptive function in patients with impaired renal function. They showed that the

absorption of the simple sugar d-xylose is reduced in patients with renal failure [6]. Gastroparesis, commonly observed in diabetic patients with renal failure, prolongs gastric emptying and delays drug absorption. Similarly, diarrhea decreases gut transit time and diminishes drug absorption by the small bowel.

The complex interaction of absorption and first-pass hepatic metabolism causes variable drug bioavailability in patients with renal impairment. For some drugs, decreased biotransformation leads to the appearance of increased amounts of active drug in the systemic circulation and enhanced bioavailability. Conversely, impaired protein binding allows more free drug to be available at the site of hepatic metabolism, thereby increasing the amount of drug removed during the hepatic first pass.

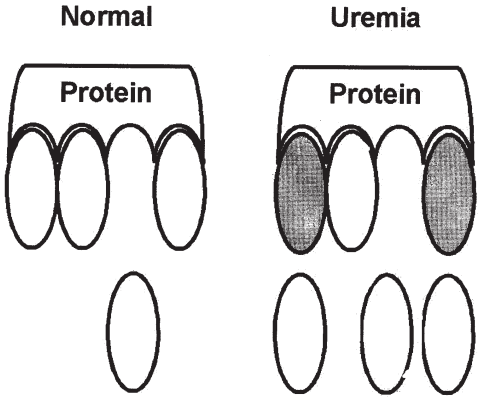

Figure 1. Protein binding defect in uremia. Displacement of drug from its binding site by the accumulation of undefined uremic toxin or a uremia-induced conformational change in the binding site geometry results in more free drug in plasma.

Distribution

Drugs disperse throughout the body at a given rate. At equilibrium, the apparent volume of distribution is the amount of the drug in the body divided by its plasma concentration. This apparent volume of distribution is a mathematical construct used to estimate the dose of a drug to be given in order to achieve a therapeutic plasma concentration rather than an actual anatomical space. Highly protein-bound drugs, or those that are water soluble, are restricted to the extracellular fluid space and have small distribution volumes. Lipid-soluble drugs penetrate body tissues and exhibit large volumes of distribution.

Renal insufficiency frequently alters drug distribution volume. Edema and ascites increase the apparent volume of distribution of highly water-soluble or protein-bound drugs. Usual doses of such drugs given to edematous patients result in lower plasma levels. Conversely, dehydration or muscle wasting decreases the volume of distribution. In these cases, usual doses result in higher plasma concentrations.

Drug binding to plasma proteins influences the volume of distribution, the quantity of free drug available for action, and the degree to which the agent can be eliminated by hepatic or renal excretion. Protein-bound drugs attach reversibly either to albumin or glycoprotein in plasma. Decreased plasma protein binding in patients with renal insufficiency increases drug action, but may also increase the rate of drug removal [7].

A protein-bound drug is in equilibrium with free drug in plasma. As illustrated in Figure 1, a combination of decreased serum albumin concentration and a reduction in albumin affinity for the drug decreases the protein binding of many drugs and shifts the equilibrium to free drug in uremic patients [8]. Even when the plasma albumin concentration is normal, the protein binding defect of some drugs correlates with the level of azotemia [9, 10].

The clinical consequences of impaired plasma protein binding in uremia are impor-

tant. Serious toxicity occurs when the total plasma concentration of a protein-bound drug is pushed into the therapeutic range by increasing the dose. If a significant protein binding defect is present, the concentration of free drug may be toxic. For such drugs, total and unbound plasma concentrations should be measured.

Predicting the clinical effects of altered protein binding in uremia is difficult. Although decreased binding results in more free drug at the site of drug action or toxicity, the distribution volume is increased resulting in lower plasma concentrations. In addition, more unbound drug is available for metabolism and excretion and decreases the half-life ($t^{1/2}$) of the drug in the body.

Metabolism

Renal failure alters drug biotransformation. Uremia slows the rate of reduction and hydrolysis reactions. Glucuronidation, sulfate conjugation, and microsomal oxidation occur at normal rates [11, 12].

The production of active or toxic metabolites is important in patients with renal failure. Metabolites frequently depend on the kidneys for their elimination from the body. Metabolite accumulation explains, in part, the high incidence of adverse drug reactions seen in renal failure.

Drug dosing recommendations for dialysis patients are usually derived from studies in patients with stable, chronic renal failure (CRF) and extrapolated to seriously ill patients with acutely decreased renal function. Acute renal failure (ARF) may spare metabolic drug clearance [12]. Drug dosing schemes extrapolated from individuals with stable CRF could result in potentially ineffectively low drug concentrations in patients with acute renal dysfunction.

Drug Dosing Calculations

When the physical examination suggests that a patient with renal impairment has a normal extracellular fluid volume, an initial drug dose equal to the dose given to a patient with normal renal function should produce therapeutic drug concentrations rapidly. A loading dose of any drug can be calculated from the following expression:

$$\text{Loading Dose} = V_d \times \text{IBW} \times Cp$$

where V_d is the drugs volume of distribution in L/kg, IBW is the patient's ideal body weight in kg, and *Cp* is the desired steady state plasma drug concentration.

For subsequent drug doses, the fraction of the normal dose recommended for a patient with renal failure can be calculated as follows:

$$Df = t½ \text{ normal} / t½ \text{ renal failure}$$

where Df is the fraction of the normal dose to be given; t½ normal is the elimination half-life of the drug in a patient with normal renal function; and t½ renal failure is the elimination half-life of the drug in a patient with renal failure. To maintain the normal dose interval in patients with renal impairment, the amount of each dose, following the loading dose, can be determined from the following relationship:

$$\text{Dose in Renal Impairment} = \text{Normal Dose} \times Df$$

The resulting dose is usually given at the same dose interval as that for patients with normal renal function. This method is effective for drugs with a narrow therapeutic range and a short plasma t1/2. Figure 2 illustrates plasma concentrations following an initial loading dose and reduction of the individual doses.

Prolonging the dose interval in dialysis patients is a convenient method to reduce drug

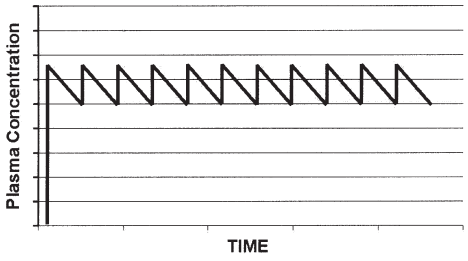

Figure 2. Plasma concentrations following a normal loading dose and reduced maintenance doses. This approach avoids high peak and low trough concentrations and is best for drugs with a narrow range between the therapeutic and toxic concentrations.

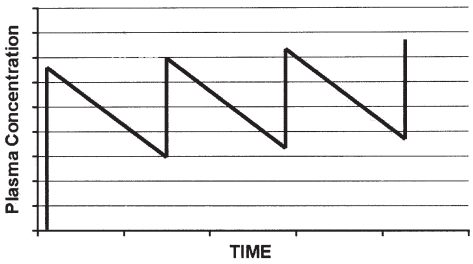

Figure 3. Plasma concentrations following a normal loading dose and repeated normal doses at a prolonged dose interval. Higher peak and lower trough concentrations result.

dosage. This method is particularly useful for drugs with a broad therapeutic range and long plasma $t^{1/2}$. If prolonging the dose interval, rather than decreasing the individual doses, is desirable, the dose interval in renal impairment can be estimated from the following expression:

Dose Interval in Renal Impairment = Normal Dose Interval / Df

If the range between therapeutic and toxic levels is too narrow, either potentially toxic or subtherapeutic plasma concentrations result. The resulting plasma concentrations from prolonging the dose interval in an individual with impaired renal function are shown in Figure 3.

Combining dose reduction and interval prolongation is a practical and convenient approach. The dosage is modified by multiplying the usual daily maintenance dose by the dose fraction. Once the average daily dose is calculated, it can be divided into convenient dosing intervals. The decision to extend the dosing interval beyond a 24-hour period should be based on the need to maintain therapeutic peak or trough levels. The dosing interval may be prolonged if the peak level is most important. When the minimum trough level must be maintained, it is preferable to modify the individual dose or use a combination of dose and interval methods to determine the correct dosing strategy. Drugs removed by dialysis and given once daily should be given after the dialysis treatment.

Drug Removal by Dialysis

Hemodialysis (HD) removes drugs from plasma by diffusion across the dialysis membrane. Diffusion proceeds from higher concentrations in the plasma to lower concentrations in the dialysate. The drug, the dialysis procedure, and the patient influence the rate and extent of drug removal by dialysis. Drugs smaller than 500 Daltons readily cross standard dialysis membranes. Dialysis does not remove drugs that are > 90 % protein bound or drugs with large volumes of distribution. Porous membranes, used for continuous renal replacement therapies, allow the filtration of much larger drugs. Since HD removes drugs by diffusion, large surface area dialyzers, increasing the blood flow rate, increasing the dialysate flow rate, and lengthening the duration of the treatment increase the amount of drug removed. The following relationship estimates the hemodialysis clearance of a drug:

$C_{HD} = C_{urea} \times (60/MW_{drug})$

where C_{HD} is the drug's clearance by hemodialysis, C_{urea} is the clearance of urea by the dialyzer, and MW_{drug} is the molecular weight of the drug [13]. The urea clearance for most standard dialyzers is about 150 mL/min.

The efficiency of drug removal by peritoneal dialysis (PD) is much less than during HD [14]. Drug removal by PD is most effective for smaller molecular weight drugs, drugs that are not extensively bound to serum proteins, and drugs distributed in the extracellular fluid. The rate and extent of small molecular weight drug removal depends on the volume of peritoneal dialysate exchanged. The following relationship estimates peritoneal drug clearance:

$$C_{PD} = C_{urea} \times \frac{\sqrt{60}}{\sqrt{MW_{drug}}}$$

where C_{PD} is the peritoneal drug clearance; C_{urea} is the peritoneal urea clearance; and MW_{drug} is the molecular weight of the drug. Peritoneal urea clearance is approximately 20 mL/min. In general, if a drug is not removed by HD, it will not be removed by PD.

Table 1 lists drugs frequently used in dialysis patients and the appropriate dosage adjustments. Suggestions for reducing the individual doses, prolonging the dose interval, or a combination of the methods are included. Recommendations for supplemental doses following HD and during CAPD are listed [15].

When medications are added to peritoneal dialysate, drug transport across the peritoneal membrane is unidirectional [16]. The addition of drugs to peritoneal dialysate results in high drug concentrations in the dialysis fluid relative to the blood. Although peritoneal dialysis does not rapidly remove drugs, many are well absorbed when placed in peritoneal dialysate because of the resulting large concentration gradient between the dialysate and the blood.

The rate and extent of drug removal by continuous renal replacement therapies (CRRT) depends on the drugs molecular weight, membrane characteristics, blood flow rate, and the addition of dialysate to the extracorporeal circuit. Molecular weight affects drug removal by diffusion during dialysis more than during convection during CRRT because of the large pore size of membranes used for CRRT. Since most drugs have a molecular weight < 1,500 Daltons, drug removal by CRRT does not depend greatly on molecular weight.

A drugs volume of distribution and binding to serum proteins are the most important factors determining removal by CRRT. Drugs with a large volume of distribution are highly tissue bound and not accessible to extracorporeal circuit in quantities sufficient to result in substantial removal by CRRT. Even if the extraction across the artificial membrane is 100%, only a small amount of a drug with a large volume of distribution is removed. A volume of distribution > 0.7 L/kg substantially decreases CRRT drug removal.

Drug protein binding also determines how much is removed during CRRT. Only unbound drug is available for elimination by CRRT. Protein binding > 80% is a substantial barrier to drug removal by convection or diffusion.

During continuous hemofiltration, a filtration rate of 10 – 30 mL/min is achieved. The addition of diffusion by continuous dialysis adds 15 – 20 mL/min. Therefore, continuous dialysis and continuous hemofiltration together provide a drug clearance 10 – 50 mL/min.

The use of porous membranes and high blood flow rates during routine HD have blurred the distinction in drug removal among renal replacement therapies. Little data are available on drug removal by these techniques. Results from studies in chronic, stable

Table 1. Dose Adjustment for Drugs Frequently Used in Dialysis Patients. Method refers to changing the dose amount (D) or the dose interval (I). Percentages are the percent of the dose for normal renal function. NA is listed for drugs where dosing is not applicable during renal replacement therapy.

Drug	Half-Life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Acarbose	3 – 9 / Prolonged	15	0.32
Acebutolol	7 – 9 / 7	20	1.2
Acetazolamide	1.7 – 5.8 / Unknown	70 – 90	0.2
Acetohexamide	1 – 1.3 / Unchanged	65 – 90	0.21
Acetohydroxamic acid	3.5 – 5 / 15 – 23	Unknown	Unknown
Acetaminophen	2 / 2	20 – 30	1 – 2
Acetylsalicylic acid (Aspirin)	2 – 3 / Unchanged	80 – 90	0.1 – 0.2
Acrivastine	1.4 – 2.1 / Unknown	50	0.6 – 0.7
Acyclovir	2.1 – 3.8 / 20	15 – 30	0.7
Adenosine	< 10 sec / Unchanged	0	Frage
Albuterol	2 – 4 / 4	7	2 – 2.5
Alcuronium	3 – 3.5 / 16	40	0.28 – 0.36
Alfentanil	1 – 3 / Unchanged	88 – 95	0.3 – 1
Allopurinol	2 – 8 / Unchanged	< 5	0.5
Alprazolam	9.5 – 19 / Unchanged	70 – 80	0.9 – 1.3
Alteplase (tPA)	0.5 / Unknown	Unknown	0.1
Altretamine	7 / Unknown	Unknown	Unknown
Amantadine	12 / 500	60	4 – 5
Amikacin	1.4 – 2.3 / 17 – 150	< 5	0.22 – 0.29
Amiloride	6 – 8 / 10 – 144	30 – 40	5 – 5.2
Amiodarone	14 – 120 days / Unchanged	96	70 – 140
Amitriptyline	24 – 40 / Unchanged	96	6 – 36
Amlodipine	35 – 50 / 50	> 95	21
Amoxapine	8 – 30 / Unknown	90	Unknown
Amoxicillin	0.9 – 2.3 / 5 – 20	15 – 25	0.26
Amphotericin	24 / Unchanged	90	4.0
Amphotericin B colloidal dispersion	24 – 30/? Unchanged	90	4.0
Amphotericin B lipid complex	19 – 45/? Unchanged	90	1.7 – 3.9
Ampicillin	0.8 – 1.5 / 7 – 20	20	0.17 – 0.31
Amrinone	2.6 – 8.3 / Unknown	20 – 40	1.3 – 1.6
Anistreplase	1.2	Unknown	.08
Astemizole	20 days / Unchanged	97	Unknown
Atenolol	6.7 / 15 – 35	3	1.1
Atovaquone	55 – 77/Unknown	99	Unknown
Atracurium	0.3 – 0.4 / Unchanged	82	0.15 – 0.18
Auranofin	70 – 80 days / Unknown	60	Unknown
Azathioprine	0.16 – 1 / Increased	20	0.55 – 0.8
Azithromycin	10 – 60 / ?	8 – 50	18
Azlocillin	0.8 – 1.5 / 5 – 6	30	0.18 – 0.27
Aztreonam	1.7 – 2.9 / 6 – 8	45 – 60	0.5 – 1.0
Benazepril	22 / 30	95	0.15
Bepridil	24 – 48 / 24 – 48	Unknown	Unknown
Betamethasone	5.5 / Unknown	65	1.4

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
D	Avoid	Unknown	Unknown	Avoid
D	30 – 50%	None	None	50%
I	Avoid	Unknown	Unknown	Avoid
I	Avoid	Unknown	None	Avoid
D	Avoid	Unknown	Unknown	Unknown
I	q8h	None	None	q6h
I	Avoid	Dose after dialysis	None	q4 – 6h
D	Unknown	Unknown	Unknown	Unknown
D,I	2.5 mg/kg q24h	Dose after dialysis	Dose for Renal Failure	3.5 mg/kg/day
D	100%	None	None	100%
D	50%	Unknown	Unknown	75%
D	Avoid	Unknown	Unknown	Avoid
D	100%	NA	NA	NA
D	25%	1/2 dose	Unknown	50%
D	100%	None	Unknown	NA
D	100%	Unknown	Unknown	100%
D	Unknown	Unknown	Unknown	Unknown
I	q7days	None	None	q48 – 72h
D,I	20% to 30% q24 – 48h	2/3 normal dose after dialysis	15 – 20 mg/L d	30 – 70% q12 – 18h
D	Avoid	NA	NA	NA
D	100%	None	None	100%
D	100%	None	Unknown	NA
D	100%	None	None	100%
D	100%	Unknown	Unknown	NA
I	q24h	Dose after dialysis	250 mg q12h	NA
I	q24 – 36h	None	Dose for Renal Failure	q24h
I	q 24 – 36h	None	Dose for Renal Failure	q 24h
I	q 24 – 36h	None	Dose for Renal Failure	q 24h
I	q12 – 24h	Dose after dialysis	250 mg q12h	q6 – 12h
D	50 – 75%	Unknown	Unknown	100%
D	100%	Unknown	Unknown	100%
D	100%	Unknown	Unknown	NA
D,I	30 – 50% q96h Unknown: 100%	25 – 50 mg Unknown: None	None Unknown	50% q48h Unknown
D	100%	Unknown	Unknown	100%
D	Avoid	None	None	None
D	50%	Yes	Unknown	75%
D	100%	None	None	None
I	q8h	Dose after dialysis	Dose for Renal Failure	q6 – 8h
D	25%	0.5 g after dialysis	Dose for Renal Failure	50 – 75%
D	25 – 50% Unknown	None None	None None	50 – 75% Unknown
D	100%	Unknown	Unknown	100%

I.19

Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Betamethasone	5.5 / Unknown	65	1.4
Betaxolol	15 – 20 / 30 – 35	45 – 60	5 – 10
Bezafibrate	2.1 / 7.8	95	0.24 – 0.3
Bisoprolol	9 – 13 / 18 – 24	30 – 35	3
Bleomycin	9 / 20	Unknown	0.3
Bleomycin	9 / 20	Unknown	0.3
Bopindolol	4 – 10 / Unchanged	Unknown	2 – 3
Bretylium	6 – 13.6 / 16 – 32	6	8.2
Bromocriptine	3 / Unknown	90 – 96	Unknown
Brompheniramine	6 / Unknown	Unknown	12
Budesonide	2 – 2.7 / Unknown	88	4.3
Bumetanide	1.2 – 1.5 / 1.5	96	0.2 – 0.5
Bupropion	10 – 21 / Unknown	82 – 88	27 – 36
Buspirone	2 – 3 / 5.8	95	5.0
Busulfan	2.5 – 3.4 / Unknown	3 – 15	1.0
Butorphanol	2 – 4 / Unknown	80	9 – 11
Capreomycin	2 / Unknown	Unknown	Unknown
Captopril	2 – 3 / 21 – 32	25 – 30	0.7 – 3
Carbamazepine	24 single; 4 – 6 chronic dosing	75	0.8 – 1.6
Carbidopa	2 / Unknown	Unknown	Unknown
Carboplatin	6 / Increased	15 – 24	0.23 – 0.28
Carmustine	1.5 / Unknown	Unknown	3.3
Carteolol	7 / 33	20 – 30	4.0
Carvedilol	5 – 8 / 5 – 8	95	1 – 2
Cefaclor	1 / 3	25	0.24 – 0.35
Cefadroxil	1.4 / 22	20	0.31
Cefamandole	1 / 6 – 11	75	0.16 – 0.25
Cefazolin	2 / 40 – 70	80	0.13 – 0.22
Cefepime	2.2 / 18	16	0.3
Cefixime	3.1 / 12	50	0.6 – 0.11
Cefmenoxime	0.8 – 1.3 / 6 – 12	43 – 75	0.27 – 0.37
Cefmetazole	1.2 / 21	75	0.18
Cefonicid	4 / 17 – 59	96	0.09 – 0.18
Cefoperazone	1.6 – 2.5 / 2.9	90	0.14 – 0.20
Ceforanide	3 / 25	80	0.17
Cefotaxime	1 / 15	37	0.15 – 0.55
Cefotetan	3.5 / 13 – 25	85	0.15
Cefoxitin	1 / 13 – 23	41 – 75	0.2
Cefpodoxime	2.5 / 26	26	0.6 – 1.2
Cefprozil	1.7 / 6	40	0.65
Ceftazidime	1.2 / 13 – 25	17	0.28 – 0.4
Ceftibutin	1.5 – 2.7/22	70	0.2
Ceftizoxime	1.4 / 35	28 – 50	0.26 – 0.42
Ceftriaxone	7 – 9 / 12 – 24	90	0.12 – 0.18

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
D	100%	Unknown	Unknown	100%
D	50%	None	None	100%
D	25%	Unknown	Unknown	50%
D	50%	Unknown	Unknown	75%
D	50%	None	Unknown	75%
D	50%	None	Unknown	Unknown
D	100%	None	None	100%
D	25%	None	None	25 – 50%
D	100%	Unknown	Unknown	Unknown
D	100%	Unknown	Unknown	NA
D	100%	Unknown	Unknown	100%
D	100%	None	None	NA
D	100%	Unknown	Unknown	NA
D	100%	None	Unknown	NA
D	100%	Unknown	Unknown	100%
D	50%	Unknown	Unknown	NA
I	q48h	Give dose after HD only	None	q24h
D,I	50% q24h	25 – 30%	None	75% q12 – 18h
D	100%	None	None	None
D	100%	Unknown	Unknown	Unknown
D	25%	1/2 dose	Unknown	50%
D	Unknown	Unknown	Unknown	Unknown
D	25%	Unknown	None	50%
D	100%	None	None	100%
D	50%	250 mg after dialysis	250 mg q8 – 12h	NA
I	q24 – 48h	0.5 – 1.0 g after dialysis	0.5 g/day	NA
I	q12h	0.5 – 1.0 g after dialysis	0.5 – 1.0 g q12h	q6 – 8h
I	q24 – 48h	0.5 – 1.0 g after dialysis	0.5 g q12h	q12h
I	q24 – 48h	1.0 g after dialysis	Dose for Renal Failure	Not recommended
D	50%	300 mg after dialysis	200 mg/day	Not recommended
D,I	0.75 g q12h	0.75 g after dialysis	0.75 g q12h	0.75 g q8h
I	q48h	Dose after dialysis	Dose for Renal Failure	q24h
D,I	0.1 g/day	None	None	None
D	100%	1 g after dialysis	None	None
I	q24 – 48h	0.5 – 1.0 g after dialysis	None	1.0 g/day
I	q24h	1 g after dialysis	1 g/day	1 g q12h
D	25%	1 g after dialysis	1 g/day	750 mg q12h
I	q24 – 48h	1 g after dialysis	1 g/day	q8 – 12h
I	q24 – 48h	200 mg after dialysis only	Dose for Renal Failure	NA
D,I	250 mg q24h	250 mg after dialysis	Dose for Renal Failure	Dose for Renal Failure
I	q48h	1 g after dialysis	0.5 g/day	q24 – 48h
D	25%	300 mg after dialysis only	Dose for Renal Failure	50%
I	q24h	1 g after dialysis	0.5 – 1.0 g/day	q12 – 24h
D	100%	Dose after dialysis	750 mg q12h	100%

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Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Cefuroxime axetil	1.2 / 17	35 – 50	0.13 – 1.8
Cefuroxime sodium	1.2 / 17	33	0.13 – 1.8
Celiprolol	4 – 5 / 5	Unknown	Unknown
Cephalexin	0.7 / 16	20	0.35
Cephalothin	0.5 – 1 / 3 – 18	65	0.26
Cephapirin	0.4 / 2.5	45 – 60	0.22
Cephradine	0.7 – 1.3 / 6 – 15	10	0.25 – 0.46
Cetirizine	7 – 10 / 20	93	0.4 – 0.6
Chloral hydrate	7 – 14 / Unknown	70 – 80	0.6
Chlorambucil	1 / Unknown	Unknown	0.86
Chloramphenicol	1.6 – 3.3 / 3 – 7	45 – 60	0.5 – 1.0
Chlorazepate (Tranxene)	39 – 85 / 36	Unknown	1.3
Chlordiazepoxide (Librium)	5 – 30 / Unchanged	94 – 97	0.3 – 0.5
Chloroquine	2 – 4 / 5 – 50 days	50 – 65	Large
Chlorpheniramine	14 – 24 / Unknown	72	6 – 12
Chlorpromazine	11 – 42 / Unchanged	91 – 99	8 – 160
Chlorpropamide	24 – 48 / 50 – 200	88 – 96	.09 – 0.27
Chlorthalidone	44 – 80 / Unknown	76 – 90	3.9
Cholestyramine	Not absorbed	None	None
Cibenzoline	7 / 22	50	4 – 5
Cidofovir	2.5/Unknown	< 6	0.3 – 0.8
Cilastin	1 / 12	44	0.22
Cilazapril	40 – 50 / > 60	Unknown	0.5 – 0.8
Cimetidine	1.5 – 2 / 5	20	0.8 – 1.3
Cinoxacin	1.2 / 12	63	0.25
Ciprofloxacin	3 – 6 / 6 – 9	20 – 40	2.5
Cisapride	7 – 10 / Unchanged	98	2.4
Cisplatin	0.3 – 0.5 / Unknown	90	0.5
Cladribine	7 – 14 / Unknown	Unknown	50 – 80
Clarithromycin	2.3 – 6 / Unknown	70	2 – 4
Clavulanic acid	1 / 3 – 4	30	0.3
Clindamycin	2 – 4 / 3 – 5	60 – 95	0.6 – 1.2
Clodronate	13 / Increased	36	0.25
Clofazamine	10 – 70 days (?)/Unknown	Unknown	Unknown
Clofibrate	15 – 17.5 / 30 – 110	92 – 97	0.14
Clomipramine	19 – 37 / Unknown	97	Unknown
Clonazepam (clonopin)	18 – 50 / Unknown	47	1.5 – 4.5
Clonidine	6 – 23 / 39 – 42	20 – 40	3 – 6
Codeine	2.5 – 3.5 / Unknown	7	3 – 4
Colchicine	19 / 40	31	2.2
Colestipol	Not absorbed	None	None
Cortisone	0.5 – 2 / 3.5	90	Unknown
Cyclophosphamide	4 – 7.5 / 10	14 – 20	0.5 – 1
Cycloserine	0.5 / Unknown	Unknown	0.11 – 0.26
Cyclosporine	3 – 16 / Unchanged	96 – 99	3.5 – 7.4
Cytarabine	0.5 – 3 / Unchanged	13	2.6

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
D	100%	Dose after dialysis	Dose for Renal Failure	NA
I	q12h	Dose after dialysis	Dose for Renal Failure	1 g q12h
D	75%	Unknown	None	100%
I	q12h	Dose after dialysis	Dose for Renal Failure	NA
I	q12h	Dose after dialysis	1 g q12h	1 g q8h
I	q12h	Dose after dialysis	1 g q12h	1 g q8h
D	25%	Dose after dialysis	Dose for Renal Failure	NA
D	30%	None	Unknown	NA
D	Avoid	None	Unknown	NA
D	Unknown	Unknown	Unknown	Unknown
D	100%	None	None	None
D	100%	Unknown	Unknown	NA
D	50%	None	Unknown	100%
D	50%	None	None	None
D	100%	None	Unknown	NA
D	100%	None	None	100%
D	Avoid	Unknown	None	Avoid
I	Avoid	NA	NA	NA
D	100%	None	None	100%
D,I	66% q24h	None	None	100% q12h
D	Unknown: avoid	Unknown	Unknown	Unknown, Avoid
D	Avoid	Avoid	Avoid	Avoid
D,I	10 – 25% q72h	None	None	50% q24 – 48h
D	25%	None	None	50%
D	Avoid	Avoid	Avoid	Avoid
D	50%	250 mg q12h (200 mg if IV)	250 mg q8h (200 mg if IV)	200 mg IV q12h
D	50%	Unknown	Unknown	50 – 100%
D	50%	Yes	Unknown	75%
D	Unknown	Unknown	Unknown	Unknown
D	50 – 75%	Dose after dialysis	None	None
D	50 – 75%	Dose after dialysis	Dose for Renal Failure	100%
D	100%	None	None	None
D	Avoid	Unknown	Unknown	Unknown
	Unknown	Unknown	Unknown	Unknown
I	Avoid	None	Unknown	q12 – 18h
D	Unknown	Unknown	Unknown	NA
D	100%	None	Unknown	NA
D	100%	None	None	100%
D	50%	Unknown	Unknown	75%
D	50%	None	Unknown	100%
D	100%	None	None	100%
D	100%	None	Unknown	100%
D	75%	1/2 dose	Unknown	100%
I	q24h	None	None	q12 – 24h
D	100%	None	None	100%
D	100%	Unknown	Unknown	100%

Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Dapsone	20 – 30/Unknown	70 – 90	1 – 1.5
Daunorubicin	18 – 27 / Unknown	Unknown	Unknown
Delavirdine	5.8 / Unknown	98	0.5
Deferoxamine	6 / Unknown	Unknown	2 – 2.5
Desipramine	18 – 26 / Unknown	92	10 – 50
Dexamethasone	3 – 4 / Unknown	70	0.8 – 1
Diazepam (Valium)	20 – 90 / Unchanged	94 – 98	0.7 – 3.4
Diazoxide	17 – 31 / 30 – 60	> 90	0.2 – 0.3
Diclofenac	1 – 2 / Unchanged	> 99	0.12 – 0.17
Dicloxacillin	0.7 / 1 – 2	95	0.16
Didanosine	0.6 – 1.6 / 4.5	< 5	1.0
Diflunisal	5 – 20 / 62	> 99	0.1 – 0.13
Digitoxin	144 – 200 / 210	94	0.6
Digoxin	36 – 44 / 80 – 120	20 – 30	5 – 8
Dilevalol	8 – 12 / 19 – 30	75	25
Diltiazem	2 – 8 / 3.5	98	9 – 10
Diphenhydramine	3.4 – 9.3 / Unknown	80	3.3 – 6.8
Dipyridamole	12 / Unknown	99	2.4
Dirithromycin	30 – 44 / Unknown	15 – 30	> 10
Disopyramide	5 – 8 / 10 – 18	54 – 81	0.8 – 2.6
Dobutamine	2 min / Unknown	Unknown	0.25
Doxacurium	1.2 – 1.6 / 3.7	28 – 34	0.12 – 0.22
Doxazosin	16 – 22 / 16 – 22	98	1 – 1.7
Doxepin	8 – 25 / 10 – 30	95	9 – 33
Doxorubicin	35 / Unchanged	80 – 85	21.5
Doxycycline	15 – 24 / 18 – 25	80 – 90	0.75
Dyphylline	1.8 – 2.3 / 12	< 3	0.8
Enalapril	11 – 24 / 34 – 60	50 – 60	Unknown
Epirubicin	35 / 35	80 – 85	10 – 40
Erbastine	13 – 16 / 23 – 26	98	1 – 2
Erythromycin	1.4 / 5 – 6	60 – 95	0.6 – 1.2
Esmolol	7 – 15 min / Unchanged		
Estazolam	8 – 24 / Unknown	93	Unknown
Ethacrynic acid	2 – 4 / Unknown	90	0.1
Ethambutol	4 / 7 – 15	10 – 30	1.6 – 3.2
Ethchlorvynol	10 – 20	35 – 50	3 – 4
Ethionamide	2.1	30	Unknown
Ethosuximide	35 – 55 / Unchanged	10	0.6 – 0.9
Etodolac	5 – 7 / Unchanged	> 99	0.4
Etomidate	4 – 5 / Unchanged	75	2 – 4.5
Etoposide	4 – 8 / 19	74 – 94	0.17 – 0.5
Famciclovir	1.6 – 2.9/10 – 22	< 25%	1.5
Famotidine	2.5 – 4 / 12 – 19	15 – 22	0.8 – 1.4
Fazadinium	1 / Unchanged	17	0.18 – 0.23
Felodipine	10 – 14 / 21 – 24	99	9 – 10

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
	Unknown	Unknown: None	Dose for Renal Failure	Unknown
D	100%	Unknown	Unknown	Unknown
	Unknown: 100%	Unknown: None	Unknown	Unknown
D	100%	Unknown	Unknown	100%
D	100%	None	None	NA
D	100%	Unknown	Unknown	100%
D	100%	None	Unknown	100%
D	100%	None	None	100%
D	100%	None	None	100%
D	100%	None	None	NA
I	q24 – 48h	Dose after dialysis	Dose for Renal Failure	Dose for Renal Failure
D	50%	None	None	50%
D	50 – 75%	None	None	100%
D,I	10 – 25% q48h	None	None	25 – 75% q36h
D	100%	None	None	Unknown
D	100%	None	None	100%
D	100%	None	None	None
D	100%	Unknown	Unknown	NA
	100%	None	Unknown	100%
I	q24 – 40h	None	None	q12 – 24h
D	100%	Unknown	Unknown	100%
D	50%	Unknown	Unknown	50%
D	100%	None	None	100%
D	100%	None	None	100%
D	100%	None	Unknown	100%
D	100%	None	None	100%
D	25%	1/3 dose	Unknown	50%
D	50%	20 – 25%	None	75 – 100%
D	100%	None	Unknown	100%
D	50%	Unknown	Unknown	50%
D	50 – 75%	None	None	None
		None	None	Unknown
D	100%	Unknown	Unknown	NA
I	Avoid	None	None	NA
I	q48h	Dose after dialysis	Dose for Renal Failure	q24 – 36h
D	Avoid	None	None	NA
D	50%	None	None	None
D	100%	None	Unknown	Unknown
D	100%	None	None	100%
D	100%	Unknown	Unknown	100%
D	50%	None	Unknown	75%
I	50% q 48 h	Dose after dialysis	Unknown	Unknown
D	10%	None	None	25%
D	100%	Unknown	Unknown	100%
D	100%	None	None	100%

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Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Fenoprofen	2 – 3 / Unchanged	> 99	0.1
Fentanyl	2.5 – 3.5 / Unchanged	79 – 87	2 – 5
Fexofenadine	14 / 19 – 25	70	Unknown
Flecainide	12 – 19.5 / 19 – 26	52	8.4 – 9.5
Fleroxacin	13 / 21 – 28	20	1.1 – 2.4
Fluconazole	22 / Unknown	12	0.7
Flucytosine	3 – 6 / 75 – 200	< 10	0.6
Fludarabine	7 – 12 / 24	Unknown	5 – 40
Flumazenil	0.7 – 1.3 / Unknown	40 – 50	0.6 – 1.1
Flunarizine	17 – 18 d / Unknown	99	43 – 78
Fluorouracil	0.1 / Unchanged	10	0.25 – 0.5
Fluoxetine (Prozac)	24 – 72 / Unchanged	94.5	12 – 42
Flurazepam (Dalmane)	47 – 100 / Unchanged	Unknown	3.4
Flurbiprofen	3 – 5 / Unchanged	99	0.1
Flutamide	4 – 6 / Unknown	Unknown	Unknown
Fluvastatin	0.5 – 1 / Unknown	Unknown	0.42
Fluvoxamine (Luvox)	12 – 15 / Unchanged	77	25
Foscarnet	3 / Prolonged (up to 100 hours)	17	0.3 – 0.6
Fosinopril	12 / 14 – 32	95	0.15
Furosemide	0.5 – 1.1 / 2 – 4	95	.07 – 0.2
Gabapentin	5 – 7 / 132	Unbound	0.7
Gallamine	2.3 – 2.7 / 6 – 20	30 – 70	0.21 – 0.24
Ganciclovir	3.6 / 30	Unknown	0.47
Ganciclovir-oral			
Gemfibrozil	7.6 / Unchanged	97 – 99	Unknown
Gentamicin	1.8 / 20 – 60	< 5	0.23 – 0.26
Glibornuride	5 – 12 / Unknown	95	0.25
Gliclazide	8 – 11 / Unknown	85 – 95	0.24
Glipizide	3 – 7 / Unknown	97	0.13 – 0.16
Glyburide	1.4 – 2.9 / Unknown	99	0.16 – 0.3
Gold sodium thiomalate	250 d / Unknown	95	5 – 9
Griseofulvin	14 / 20	Unknown	1.6
Guanabenz	12 – 14 / Unknown	90	10 – 12
Guanadrel	4 – 10 / 19	20	11.5
Guanethidine	120 – 140 / Unknown	< 5	Unknown
Guanfacine	12 – 23 / 15 – 25	65	4 – 6.5
Haloperidol	10 – 19 / Unknown	90 – 92	14 – 21
Heparin	0.3 – 2 / Unchanged	> 90	0.06 – 0.1
Hexobarbital	3.5 – 4 / Unknown	65	1.1
Hydralazine	2 – 4.5 / 7 – 16	87	0.5 – 0.9
Hydrocortisone	1.5 – 2 / Unknown	Unknown	Unknown
Hydroxyurea	Unknown	Unknown	0.5
Hydroxyzine	14 – 20 / Unknown	Unknown	19.5

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
D	100%	None	None	100%
D	100%	NA	NA	NA
I	q24h	Unknown	Unknown	q12 – 24h
D	50 – 75%	None	None	100%
D	50%	400 mg after dialysis	400 mg/day	NA
D	100%	200 mg after dialysis	Dose for Renal Failure	100%
I	q24h	Dose after dialysis	0 .5 – 1.0 g/day	q16h
D	50%	Unknown	Unknown	75%
D	100%	None	Unknown	NA
D	100%	None	None	None
D	100%	Yes	Unknown	100%
D	100%	Unknown	Unknown	NA
D	100%	None	Unknown	NA
D	100%	None	None	100%
D	100%	Unknown	Unknown	Unknown
D	100%	Unknown	Unknown	100%
D	100%	None	Unknown	NA
D	6 mg/kg	Dose after dialysis	Dose for Renal Failure	15 mg/kg
D	75% to 100%	None	None	100%
D	100%	None	None	NA
D,I	300 mg qd	300mg load, then 200 – 300 after each dialysis		300q 12 – 24h
D	Avoid	NA	NA	Avoid
I	q48 – 96h	Dose after dialysis	Dose for Renal Failure	2.5 mg/kg day
D,I	Unknown: 500 mg q 48 – 96h	Unknown:Dose after dialysis	Dose for Renal Failure	NA
D	100%	None	Unknown	100%
D,I	20 – 30% q24 – 48h	2/3 normal dose after dialysis	3 – 4 mg/L day	30 – 70% q12h
D	Unknown	Unknown	Unknown	Avoid
D	Unknown	Unknown	Unknown	Avoid
D	100%	Unknown	Unknown	Avoid
D	Avoid	None	None	Avoid
D	Avoid	None	None	Avoid
D	100%	None	None	None
D	100%	Unknown	Unknown	100%
I	q24 – 48h	Unknown	Unknown	q12 – 24h
I	q24 – 36h	Unknown	Unknown	Avoid
D	100%	None	None	100%
D	100%	None	None	100%
D	100%	None	None	100%
D	100%	None	Unknown	NA
I	q8 – 16h	None	None	q8h
D	100%	Unknown	Unknown	100%
D	20%	Unknown	Unknown	50%
D	Unknown	100%	100%	100%

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Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Ibuprofen	2 – 3.2 / Unchanged	99	0.15 – 0.17
Idarubicin	36 – 70 / Unknown	Unknown	Unknown
Ifosfamide	4 – 10 / Unknown	Unknown	0.4 – 0.64
Iloprost	0.3 – 0.5 / Unknown	Unknown	0.7
Imipenem	1 / 4	13 – 21	0.17 – 0.3
Imipramine	12 – 24 / Unknown	96	10 – 20
Indapamide	14 – 18 / Unchanged	76 – 79	0.3 – 1.3
Indinavir	1.8 / Unknown	60	Unknown
Indobufen	6 – 7 / 27 – 33	> 99	0.18 – 0.2
Indomethacin	4 – 12 / Unchanged	99	0.12
Insulin	2 – 4 / Increased	5	0.15
Ipratropium	1.6 / Unknown	Unknown	4.6
Isoniazid	0.7 – 4 / 8 – 17	4 – 30	0.75
Isosorbide	0.15 – 0.5 / 4	72	1.5 – 4
Isradipine	1.9 – 4.8 / 10 – 11	97	3 – 4
Itraconazole	21 / 25	99	10
Kanamycin	1.8 – 5 / 40 – 96	< 5	0.19 – 0.23
Ketamine	2 – 3.5 / Unchanged	Unknown	1.8 – 3.1
Ketanserin	14 – 19 / 25 – 35	95	3 – 6
Ketoconazole	1.5 – 3.3 / 3.3	99	1.9 – 3.6
Ketoprofen	1.5 – 4 / Unchanged	99	0.11
Ketorolac	4 – 6 / 10	> 99	0.13 – 0.25
Labetolol	3 – 9 / Unchanged	50	5.6
Lamivudine	5 – 11 / 20	36	0.83
Lamotrigine	25 – 30 / Unknown	0.55	0.9 – 1.3
Lansoprazole	1.3 – 2.9 / Unchanged	> 98	Unknown
Levodopa	0.8 – 1.6 / Unknown	5 – 8	0.9 – 1.6
Levofloxacin	4 – 8 / 76	24 – 38	1.1 – 1.5
Lidocaine	2 – 2.2 / 1.3 – 3	60 – 66	1.3 – 2.2
Lincomycin	4 – 5 / 10 – 20	70 – 80	0.31 – 0.6
Lisinopril	30 / 40 – 50	0 – 10	0.13 – 0.15
Lispro Insulin	1 / Prolonged	Unknown	0.26 – 0.36
Lithium carbonate	14 – 28 / 40	None	0.5 – 0.9
Lomefloxacin	8 / 44	15	1.8 – 3.1
Loracarbef	0.8 – 1.3 / 32	25	0.3 – 0.4
Lorazepam (Ativan)	5 – 10 / 32 – 70	87	0.9 – 1.3
Losartan	3 / 4 – 6	30	0.4
Lovastatin	1.1 – 1.7 / Unchanged	> 95	Unknown
Low-molecular-weight heparin	2.2 – 6 / 3.6 – 5	Unknown	0.06 – 0.13
Maprotiline (Ludiomil)	48 / Unknown	Unknown	Unknown
Meclofenamic acid	3 / Unchanged	> 99	Unknown
Mefenamic acid	3 – 4 / Unchanged	Unknown	Unknown

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
D	100%	None	None	100%
	Unknown	Unknown	Unknown	Unknown
D	75%	Unknown	Unknown	100%
D	50%	Unknown	Unknown	100%
D	25%	Dose after dialysis	Dose for Renal Failure	50%
D	100%	None	None	NA
D	Avoid	None	None	NA
	100%	None	Dose for Renal Failure	Unknown
D	25%	Unknown	Unknown	NA
D	100%	None	None	100%
D	50%	None	None	75%
D	100%	None	None	100%
D	50%	Dose after dialysis	Dose for Renal Failure	Dose for Renal Failure
D	100%	10 – 20 mg	None	100%
D	100%	None	None	100%
D	50%	100 mg q12 – 24h	100 mg q12 – 24h	100 mg q12 – 24h
D,I	20 – 30% q24 – 48h	2/3 normal dose after dialysis	15 – 20 mg/L d	30 – 70% q12H
D	100%	Unknown	Unknown	100%
D	100%	None	None	100%
D	100%	None	None	None
D	100%	None	None	100%
D	50%	None	None	50%
D	100%	None	None	100%
D,I	25 mg qd (50 mg first dose)	Dose after dialysis	Dose for Renal Failure	50 – 150 mg qd (full first dose)
	100%	Unknown	Unknown	100%
D	100%	Unknown	Unknown	Unknown
D	100%	Unknown	Unknown	100%
D	25 – 50%	Dose for Renal Failure	Dose for Renal Failure	50%
D	100%	None	None	100%
I	q12 – 24h	None	None	NA
D	25 – 50%	20%	None	50 – 75%
D	50%	None	None	None
D	25 – 50%	Dose after dialysis	None	50 – 75%
D	50%	Dose for Renal Failure	Dose for Renal Failure	NA
I	q3 – 5days	Dose after dialysis	Dose for Renal Failure	q24h
D	100%	None	Unknown	100%
D	100%	Unknown	Unknown	100%
D	100%	Unknown	Unknown	100%
D	50%	Unknown	Unknown	100%
D	100%	Unknown	Unknown	NA
D	100%	None	None	100%
D	100%	None	None	100%

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Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Mefloquine	15 – 33 days / Unknown	98	20
Melphalan	1.1 – 1.4 / 4 – 6	90	0.6 – 0.75
Meperidine (Demerol)	2 – 7 / 7 – 32	70	4 – 5
Meprobamate	9 – 11 / Unchanged	0 – 30	0.5 – 0.8
Meropenem	1.1 / 6 – 8	Low	0.35
Metaproterenol	2 – 6 / Unknown	10	7.6
Metformin	1 – 5 / Prolonged	Negligible	1 – 4
Methadone	13 – 58 / Unknown	60 – 90	3 – 6
Methenamine mandelate	4 / Unknown	Unknown	Unknown
Methicillin	0.5 – 1 / 4	35 – 60	0.31
Methimazole	3 – 6 / Unchanged	None	0.6
Methotrexate	8 – 12 / Increased	45 – 50	0.76
Methyldopa	1.5 – 6 / 6 – 16	< 15	0.5
Methylprednisolone	1.9 – 6 / Unchanged	40 – 60	1.2 – 1.5
Metoclopramide	2.5 – 4 / 14 – 15	40	2 – 3.4
Metocurine	3.5 – 5.8 / 11.3	70	0.42 – 0.57
Metolazone	4 – 20 / Unknown	95	1.6
Metoprolol	3.5 / 2.5 – 4.5	8	5.5
Metronidazole	6 – 14 / 7 – 21	20	0.25 – 0.85
Mexiletine	8 – 13 / 16	70 – 75	5.5 – 6.6
Mezlocillin	0.6 – 1.2 / 2.6 – 5.4	20 – 46	0.18
Miconazole	20 – 24 / Unchanged	90	Large
Midazolam	1.2 – 12.3 / Unchanged	93 – 96	1.0 – 6.6
Midodrine	0.5 / Unknown	Unknown	Unknown
Miglitol	3 – 5 / Prolonged	Unknown	Unknown
Milrinone	1 / 1.5 – 3	Unknown	0.25 – 0.35
Minocycline	12 – 16 / 12 – 18	70	1.0 – 1.5
Minoxidil	2.8 – 4.2 / Unchanged	0	2 – 3
Mitomycin C	0.5 – 1 / Unknown	Unknown	0.5
Mitoxantrone	23 – 40 / Unknown	75	200 – 300
Mivacurium	1.5 – 3	Unknown	0.1
Moricizine	2 / 3	95	> 5.0
Morphine	1 – 4 / Unchanged	20 – 30	3.5
Moxalactam (Latamoxef)	2.3 / 18 – 23	35 – 59	0.18 – 0.4
Nabumetone	24 / Unchanged	> 99	0.11
N-Acetylcysteine	2.3 – 6 / Unknown	50	0.33 – 0.47
N-Acetyl-procainamide	6 – 8 / 42 – 70	10 – 20	1.5 – 1.7
Nadolol	19 / 45	28	1.9
Nafcillin	0.5 / 1.2	85	0.35
Nalidixic acid	6 / 21	90	0.25 – 0.35
Naloxone	1 – 1.5 / Unknown	54	3
Naproxen	12 – 15 / Unchanged	99	0.1
Nefazodone (Serzone)	2 – 4 / Unchanged	99	0.22 – 0.87
Nelfinavir	1.8 – 3.4 / Unknown	Unknown	Unknown
Neostigmine	1.3 / 3.0	None	0.5 – 1.0

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
	100%	None	None	Unknown
D	50%	Unknown	Unknown	75%
D	50%	Avoid	None	Avoid
I	q12 – 18h	None	Unknown	NA
D,I	250 – 500 mg q24h	Dose after dialysis	Dose for Renal Failure	250 – 500 mg q12h
D	100%	Unknown	Unknown	100%
D	Avoid	Unknown	Unknown	Avoid
D	50 – 75%	None	None	NA
D	Avoid	NA	NA	NA
I	q8 – 12h	None	None	q6 – 8h
D	100%	Unknown	Unknown	100%
D	Avoid	None	None	50%
I	q12 – 24h	250 mg	None	q8 – 12h
D	100%	Yes	Unknown	100%
D	50%	None	Unknown	50 – 75%
D	50%	Unknown	Unknown	50%
D	100%	None	None	NA
D	100%	50 mg	None	100%
D	50%	Dose after dialysis	Dose for Renal Failure	100%
D	50 – 75%	None	None	None
I	q8h	None	None	q6 – 8h
D	100%	None	None	None
D	50%	NA	NA	NA
	Unknown	5mg q8h	Unknown	5 – 10mg q8h
D	Avoid	Unknown	Unknown	Avoid
D	50 – 75%	Unknown	Unknown	100%
D	100%	None	None	100%
D	100%	None	None	100%
D	75%	Unknown	Unknown	Unknown
D	100%	Unknown	Unknown	100%
D	50%	Unknown	Unknown	Unknown
D	100%	None	None	100%
D	50%	None	Unknown	75%
I	q24 – 48h	Dose after dialysis	Dose for Renal Failure	q12 – 24h
D	100%	None	None	100%
D	75%	Unknown	Unknown	100%
D,I	25% q12 – 18h	None	None	50% q8 – 12h
D	25%	40 mg	None	50%
D	100%	None	None	100%
D	Avoid	Avoid	Avoid	NA
D	100%	NA	NA	100%
D	100%	None	None	100%
D	100%	Unknown	Unknown	NA
	Unknown	Unknown	Unknown	Unknown
D	25%	Unknown	Unknown	50%

I.19

Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Netlimicin	1 – 3 / 35 – 72	< 5	0.16 – 0.30
Nevirapine	40 / ?	60	1.2 – 1.4
Nicardipine	5 / 5 – 7	98 – 99	0.8
Nicotinic acid	0.5 – 1 / Unknown	Unknown	Unknown
Nifedipine	4 – 5.5 / 5 – 7	97	1.4
Nimodipine	1 – 2.8 / 22	98	0.9 – 2.3
Nisoldipine	6.6 – 7.9 / 6.8 – 9.7	99	2.3 – 7.1
Nitrazepam	18 – 36 / Unknown	Unknown	Unknown
Nitrofurantoin	0.5 / 1	20 – 60	0.3 – 0.7
Nitroglycerine	2 – 4 min / Unchanged	Unknown	2 – 3
Nitroprusside	< 10 min / < 10 min	0	0.2
Nitrosoureas	Short / Unknown	Unknown	Unknown
Nizatidine	1.3 – 1.6 / 5.3 – 8.5	28 – 35	0.8 – 1.3
Norfloxacin	3.5 – 6.5 / 8	14	< 0.5
Nortriptyline (Pamelor)	25 – 38 / 15 – 66	95	15 – 23
Ofloxacin	5 – 8 / 28 – 37	25	1.5 – 2.5
Omeprazole	0.5 – 1 / Unchanged	95	Unknown
Ondansetron	2.5 – 5.5 / Unchanged	75	2
Orphenadrine	16 / Unknown	Unknown	Unknown
Ouabain	21 / 60 – 70	40	Unknown
Oxaproxin	50 – 60 / Unchanged	> 99	0.2
Oxatomide	20 / Unknown	91	Unknown
Oxazepam (Serax)	5 – 10 / 25 – 90	97	0.6 – 1.6
Oxcarbazepine	8 – 9 / Unknown	40	0.7 – 0.8
Paclitaxel	9 – 30 / Unknown	Unknown	30 – 60
Pancuronium	1.7 – 2.2 / 4.3 – 8.2	70 – 85	0.15 – 0.38
Paroxetine (Paxil)	10 – 16 / 30	95	13
PAS	1.0 / Unknown	15 – 50	0.11 – 24
Penbutolol	22 / 24	> 95	Unknown
Penicillamine	1.5 – 3 / Increased	80	Unknown
Penicillin G	0.5 / 6 – 20	50	0.3 – 0.42
Penicillin VK	0.6 / 4.1	50 – 80	0.5
Pentamidine	29 / 118	69	55 – 462
Pentazocine (Talwin)	2 – 5 / Unknown	50 – 75	5
Pentobarbital	18 – 48 / Unchanged	60 – 70	1.0
Pentopril	2 – 3 / 10 – 14	60	0.8
Pentoxifylline	0.8 / Unchanged	None	2.4 – 4.2
Perfloxacin	10 / 15	25 – 43	2.0
Perindopril	5 / 27	20	0.6 – 0.8
Phenelzine (Nardil)	1.5 – 4 / Unknown	Unknown	Unknown
Phenobarbital	60 – 150 / 117 – 160	40 – 60	0.7 – 1
Phenylbutazone	50 – 100 / Unchanged	99	0.09 – 0.17
Phenytoin	24 / Unchanged	90	1.0
Pindolol	2.5 – 4 / 3 – 4	50	1.2
Pipecuronium	2.3 / 4.4	Unknown	0.31

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
D,I	10 – 20% q24 – 48h	2/3 normal dose after dialysis	3 – 4 mg/L/day	20 – 60% q12h
D	Unknown: 100%	Unknown: None	Dose for Renal Failure	Unknown
D	100%	None	None	100%
D	25%	Unknown	Unknown	50%
D	100%	None	None	100%
D	100%	None	None	100%
D	100%	None	None	100%
D	100%	Unknown	Unknown	NA
D	Avoid	NA	NA	NA
D	100%	Unknown	Unknown	100%
D	100%	None	None	100%
D	25 – 50%	None	Unknown	Unknown
D	25%	Unknown	Unknown	50%
I	Avoid	NA	NA	NA
D	100%	None	None	NA
D	25 – 50%	100 mg bid	Dose for Renal Failure	300 mg/day
D	100%	Unknown	Unknown	Unknown
D	100%	Unknown	Unknown	100%
D	100%	Unknown	Unknown	NA
I	q36 – 48h	None	None	q24 – 36h
D	100%	None	None	100%
D	100%	None	None	NA
D	100%	None	Unknown	100%
D	100%	Unknown	Unknown	Unknown
D	100%	Unknown	Unknown	100%
D	Avoid	Unknown	Unknown	50%
D	50%	Unknown	Unknown	NA
D	50%	Dose after dialysis	Dose for Renal Failure	Dose for Renal Failure
D	100%	None	None	100%
D	Avoid	1/3 dose	Unknown	Avoid
D	20 – 50%	Dose after dialysis	Dose for Renal Failure	75%
D	100%	Dose after dialysis	Dose for Renal Failure	NA
I	q48h	None	None	None
D	50%	None	Unknown	75%
D	100%	None	Unknown	100%
D	50%	Unknown	Unknown	50 – 75%
D	100%	Unknown	Unknown	100%
D	100%	None	None	100%
D	50%	25 – 50%	Unknown	75%
D	100%	Unknown	Unknown	NA
I	q12 – 16h	Dose after dialysis	1/2 normal dose	q8 – 12h
D	100%	None	None	100%
D	100%	None	None	None
D	100%	None	None	100%
D	25%	Unknown	Unknown	50%

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Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Piperacillin	0.8 – 1.5 / 3.3 – 5.1	30	0.18 – 0.30
Piretanide	1.4 / 1.6 – 3.4	94	0.3
Piroxicam	45 – 55 / Unchanged	> 99	0.12 – 0.15
Plicamycin	2 / Unknown	Low	Unknown
Plicamycin	2 / Unknown	Low	Unknown
Pravastatin	0.8 – 3.2 / Unchanged	Unknown	Unknown
Prazepam	36 – 200 / 36	Unknown	Unknown
Prazosin	2 – 3 / 2 – 3	97	1.2 – 1.5
Prednisolone	2.5 – 3.5 / Unchanged	Saturable	2.2
Prednisone	2.5 – 3.5 / Unchanged	Saturable	2.2
Primaquine	4 – 7 / Unknown	Unknown	3 – 4
Primidone	5 – 15 / Unchanged	20 – 30	0.4 – 1
Probenecid	5 – 8 / Unchanged	85 – 95	0.15
Probucol	23 – 47 days / Unknown	Unknown	Unknown
Procainamide	2.5 – 4.9 / 5.3 – 5.9	15	2.2
Promethazine	12 / Unknown	93	13.5
Promethazine	9 – 12 / Unknown	Unknown	Large
Propafenone	5 / Unknown	> 95	3.0
Propofol	3 – 4.5 / Unchanged	Unknown	3.0 – 14.4
Propoxyphene (Darvon)	9 – 15 / 12 – 20	78	16
Propranolol	2 – 6 / 1 – 6	93	2.8
Propylthiouracil	1 – 2 / Unchanged	80	0.3 – 0.4
Protryptyline (Vivactil)	54 – 98 / Unknown	92	15 – 31
Pyrazinimide	9 / 26	5	0.75 – 1.3
Pyridostigmine	1.5 – 2 / 6	Unknown	0.8 – 1.4
Pyrimethamine	80 / Unchanged	27	2.9
Quazepam	20 – 40 / Unknown	95	Unknown
Quinapril	1 – 2 / 6 – 15	97	1.5
Quinidine	6 / 4 – 14	70 – 95	2 – 3.5
Quinine	5 – 16 / Unchanged	70	0.7 – 3.7
Ramipril	5 – 8 / 15	55 – 70	1.2
Ranitidine	1.5 – 3 / 6 – 9	15	1.2 – 1.8
Reserpine	46 – 168 / 87 – 323	96	Unknown
Ribavirin	30 – 60 / Unknown	0	9 – 15
Rifabutin	16 – 69 / Unchanged	71 – 89	8.2 – 9.3
Rifampin	1.5 – 5 / 1.8 – 11	60 – 90	0.9
Ritonavir	3 / Unknown	98 – 99	0.4
Saquinavir	12 / ?	98	10
Secobarbital	20 – 35 / Unknown	44	1.5 – 2.5
Sertraline (Zoloft)	24 / Unchanged	97	25
Simvastatin	Unknown	> 95	Unknown
Sodium valproate	6 – 15 / Unchanged	90	0.19 – 0.23
Sotalol	7.5 – 15 / 56	< 1	1.3
Sparfloxacin	15 – 20 / 38.5	35 – 55	4.5

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
I	q8h	Dose after dialysis	Dose for Renal Failure	q6 – 8h
D	100%	None	None	NA
D	100%	None	None	100%
D	50%	Unknown	Unknown	Unknown
D	50%	Unknown	Unknown	Unknown
D	100%	Unknown	Unknown	100%
D	100%	Unknown	Unknown	NA
D	100%	None	None	100%
D	100%	Yes	Unknown	100%
D	100%	None	Unknown	100%
	100%	Unknown	Unknown	Unknown
I	q12 – 24h	1/3 dose	Unknown	Unknown
D	Avoid	Avoid	Unknown	Avoid
D	100%	Unknown	Unknown	100%
I	q8 – 24h	200 mg	None	q6 – 12h
D	100%	None	None	100%
D	100%	Unknown	Unknown	100%
D	100%	None	None	100%
D	100%	Unknown	Unknown	100%
D	Avoid	None	None	NA
D	100%	None	None	100%
D	100%	Unknown	Unknown	100%
D	100%	None	None	NA
D	Avoid	Avoid	Avoid	Avoid
D	20%	Unknown	Unknown	35%
D	100%	None	None	None
D	Unknown	Unknown	Unknown	NA
D	75%	25%	None	75 – 100%
D	75%	100 – 200 mg	None	100%
I	q24h	Dose after dialysis	Dose for Renal Failure	q8 – 12h
D	25 – 50%	20%	None	50 – 75%
D	25%	1/2 dose	None	50%
D	Avoid	None	None	100%
D	50%	Dose after dialysis	Dose for Renal Failure	Dose for Renal Failure
	100%	None	None	Unknown
D	50 – 100%	None	Dose for Renal Failure	Dose for Renal Failure
	100%	None	Dose for Renal Failure	Unknown
	100%	None	Dose for Renal Failure	Unknown
D	100%	None	None	NA
D	100%	Unknown	Unknown	NA
D	100%	Unknown	Unknown	100%
D	100%	None	None	None
D	15 – 30%	80 mg	None	30%
D,I	50% q 48h	dose for GFR < 10	Unknown	50 – 75%

→

Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Spectinomycin	1.6 / 16 – 29	5 – 20	0.25
Spironolactone	10 – 35 / Unchanged	98	Unknown
Stavudine	1.0 – 1.4/5.5 – 8	< 1	0.5
Streptokinase	0.6 – 1.5 / Unknown	Unknown	0.02 – .08
Streptomycin	2.5 / 100	35	0.26
Streptozotocin	0.25 / Unknown	Unknown	0.5
Succinylcholine	3 / Unknown	Unknown	Unknown
Sufentanil	2 – 5 / Unchanged	92	2 – 3
Sulbactam	1 / 10 – 21	30	0.25 – 0.5
Sulfamethoxazole	10 / 20 – 50	50	0.28 – 0.38
Sulfinpyrazone	2.2 – 5 / Unchanged	> 95	0.06
Sulfisoxazole	3 – 7 / 6 – 12	85	0.14 – 0.28
Sulindac	8 – 16 / Unchanged	95	Unknown
Sulotroban	0.7 – 3 / 9 – 39	Unknown	Unknown
Tamoxifen	18 / Unknown	> 98	20
Tazobactam	1 / 7	22	0.21
Teicoplanin	33 – 190 / 62 – 230	60 – 90	0.5 – 1.2
Temazepam (Restoril)	4 – 10 / Unknown	96	1.3 – 1.5
Teniposide	6 – 10 / Unknown	99	0.2 – 0.7
Terazosin	9 – 12 / 8 – 12	90 – 94	0.5 – 0.9
Terbutaline	3 / Unknown	15 – 25	0.9 – 1.5
Terfenadine	16 – 23 / Unknown	97	Unknown
Tetracycline	6 – 10 / 57 – 108	55 – 90	> 0.7
Theophylline	4 – 12 / Unchanged	55	0.4 – 0.7
Thiazides	6 – 8 / 12 – 20	40	3.0
Thiopental	3.8 / 6 – 18	72 – 86	1 – 1.5
Ticarcillin	1.2 / 11 – 16	45 – 60	0.14 – 0.21
Ticlopidine	24 – 33 / Unknown	98	Unknown
Timolol	2.7 / 4	60	1.7
Tobramycin	2.5 / 27 – 60	< 5	0.22 – 0.33
Tocainide	14 / 22 – 27	10 – 20	3.2
Tolazamide	4 – 7 / Unknown	94	Unknown
Tolbutamide	4 – 6 / Unchanged	95 – 97	0.1 – 0.15
Tolmetin	1 – 1.5 / Unchanged	> 99	0.1 – 0.14
Topiramate	19 – 23 / 48 – 60	9 – 17	0.6 – 0.8
Topotecan	4 – 6 / Prolonged	Unknown	40
Torsemide	2 – 4 / 4 – 5	97 – 99	0.14 – 0.19
Tranexamic acid	1.5 / Unknown	3	Unknown
Tranylcypromine (Parnat)	1.9 – 3.5 / Unknown	Unknown	Unknown
Triazolam (Halcion)	2 – 4 / Unchanged	85 – 95	Unknown
Trihexyphenidyl	10 / Unknown	Unknown	Unknown
Trimethadione	12 – 24 / Unknown	None	Unknown
Trimethoprim	9 – 13 / 20 – 49	30 – 70	1 – 2.2
Trimetrexate	4 – 22 / Unknown	95	0.6 (10 – 31L/m^2)
Trimipramine (Surmontril)	24 / Unknown	90 – 96	31

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
D	100%	None	None	None
I	Avoid	NA	NA	Avoid
D,I	50% q 24 h	Dose after dialysis	Unknown	Unknown
D	100%	NA	NA	100%
I	q72 – 96h	1/2 normal dose after dialysis	20 – 40 mg/L day	q24 – 72h
D	50%	Unknown	Unknown	Unknown
D	100%	Unknown	Unknown	100%
D	100%	NA	NA	NA
I	q24 – 48h	Dose after dialysis	0.75 – 1.5 g/day	750 mg q12h
I	q24h	1 g after dialysis	1 g/day	q18h
D	Avoid	None	None	100%
I	q12 – 24h	2 g after dialysis	3 g/day	NA
D	100%	None	None	100%
D	10%	Unknown	Unknown	Unknown
D	100%	Unknown	Unknown	100%
D	50%	1/3 dose after dialysis	Dose for Renal Failure	75%
I	q72h	Dose for Renal Failure	Dose for Renal Failure	q48h
D	100%	None	None	NA
D	100%	None	None	100%
D	100%	Unknown	Unknown	100%
D	Avoid	Unknown	Unknown	50%
D	100%	None	None	NA
I	q24h	None	None	q12 – 24h
D	100%	1/2 dose	Unknown	100%
D	Avoid	NA	NA	NA
D	75%	NA	NA	NA
D,I	1 – 2 g q12h	3 g after dialysis	Dose for Renal Failure	1 – 2 g q8h
D	100%	Unknown	Unknown	100%
D	100%	None	None	100%
D,I	20 – 30% q24 – 48h	2/3 normal dose after dialysis	3 – 4 mg/L/day	30 – 70% q12h
D	50%	200 mg	None	100%
D	100%	Unknown	Unknown	Avoid
D	100%	None	None	Avoid
D	100%	None	None	100%
D	25%	Unknown	Unknown	50%
D	25%	Unknown	Unknown	50%
D	100%	None	None	NA
D	10%	Unknown	Unknown	Unknown
D	Unknown	Unknown	Unknown	NA
D	100%	None	None	NA
D	Unknown	Unknown	Unknown	Unknown
I	q12 – 24h	Unknown	Unknown	q8 – 12h
I	q24h	Dose after dialysis	q24h	q18h
D	Unknown: Avoid ?	Unknown	Unknown	Unknown
D	100%	None	None	NA

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Drug	Half-life (hours) Normal/Renal Failure	Protein Binding (Percent)	Volume of Distribution (L/kg)
Tripelennamine	3 – 4.5 / Unknown	Unknown	10
Triprolidine	5 / Unknown	Unknown	Unknown
Tubocurarine	0.5 – 4 / 5.5	30 – 50	0.22 – 0.39
Urokinase	Unknown	Unknown	Unknown
Valacyclovir	3/14	15%	Unknown
Vancomycin	6 – 8 / 200 – 250	10 – 50	0.47 – 1.1
Vecuronium	0.5 – 1.3 / Unchanged	30	0.18 – 0.27
Venlafaxine (Effexor)	4 /6 – 8	27	6 – 7
Verapamil	3 – 7 / 2.4 – 4	83 – 93	3 – 6
Vidarabine	1.5 / Unknown	25	0.7
Vigabatrin	5 – 7 / 13 – 15	None	0.8
Vinblastine	1 – 1.5 / Unknown	75	13 – 40
Vincristine	1 – 2.5 / Unknown	75	5 – 11
Trazodone	6 – 11 / Unknown	89 – 95	1 – 2
Triamcinolone	1.9 – 6 / Unchanged	Unknown	1.4 – 2.1
Triamterene	2 – 12 / 10	40 – 70	2.2 – 3.7
Vinorelbine	20 – 40 / Unknown	15	75
Warfarin	34 – 45 / Unchanged	99	0.15
Zafirlukast	10 / Unchanged	99	Unknown
Zalcitabine	1 – 2 / > 8	< 4	0.54
Zidovudine (AZT)	1.1 – 1.4 / 1.4 – 3	10 – 30	1.4 – 3
Zileuton	2.3 / Unchanged	> 90	2.3

HD are often extrapolated to make dosing recommendations for patients with ARF or those treated with very high flux dialysis. Underestimating drug removal in these circumstances risks ineffective therapy.

Drug Level Monitoring

Plasma drug concentrations guide drug therapy when the relationship between drug levels and efficacy or toxicity is known. These measurements are most important for drugs with a narrow therapeutic range. They may also be useful when drug level-related pharmacological effects are difficult to measure.

If a loading dose is not given, 3 – 4 doses of the drug should be administered before serum levels are measured. This approach ensures that a steady state serum concentration has been established. For some drugs, both maximum and minimum concentrations are relevant. Peak levels are most meaningful when measured after rapid drug distribution has occurred. Conversely, minimum concentrations

Method	Renal Failure Dose	Dose after Hemodialysis	Dose During CAPD	Dose During CRRT
D	Unknown	Unknown	Unknown	NA
D	Unknown	Unknown	Unknown	NA
D	Avoid	Unknown	Unknown	50%
D	Unknown	Unknown	Unknown	Unknown
D,I	0.5 g q24h	Dose after dialysis	Dose for Renal Failure	Unknown
D,I	500 mg q48 – 96h	Dose for Renal Failure	Dose for Renal Failure	500 mg q24 – 48h
D	100%	Unknown	Unknown	100%
D	50%	None	Unknown	NA
D	100%	None	None	100%
D	75%	Infuse after dialysis	Dose for Renal Failure	100%
D	25%	Unknown	Unknown	50%
D	100%	Unknown	Unknown	100%
D	100%	Unknown	Unknown	100%
D	Unknown	Unknown	Unknown	NA
D	100%	Unknown	Unknown	Unknown
I	Avoid	NA	NA	Avoid
D	100%	Unknown	Unknown	100%
D	100%	None	None	None
D	100%	Unknown	Unknown	100%
I	q24h	Unknown	Unknown	Unknown
D,I	100 mg q8h 100%	Dose for Renal Failure None	Dose for Renal Failure Unknown	100 mg q8h 100%

q = every, h = hour, bid = twice daily

are usually measured just before giving the next scheduled dose. A practical schema for drug prescribing in patients with renal impairment is shown in Figure 4.

Patients with renal disease are heterogeneous and their response to drug therapy is variable. Dosage nomograms, drug tables, and computer-assisted dosing recommendations provide guidelines for an initial drug administration in patients with decreased renal function. Individualizing the dose regimen for each patient requires continuing evaluation of the therapeutic response for drug efficacy and toxicity.

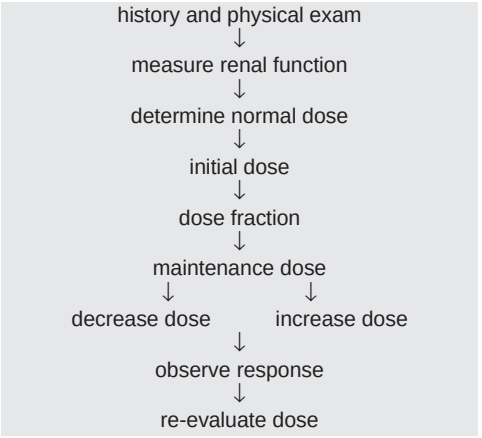

Figure 4. A practical schema for drug dosing in dialysis patients.

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