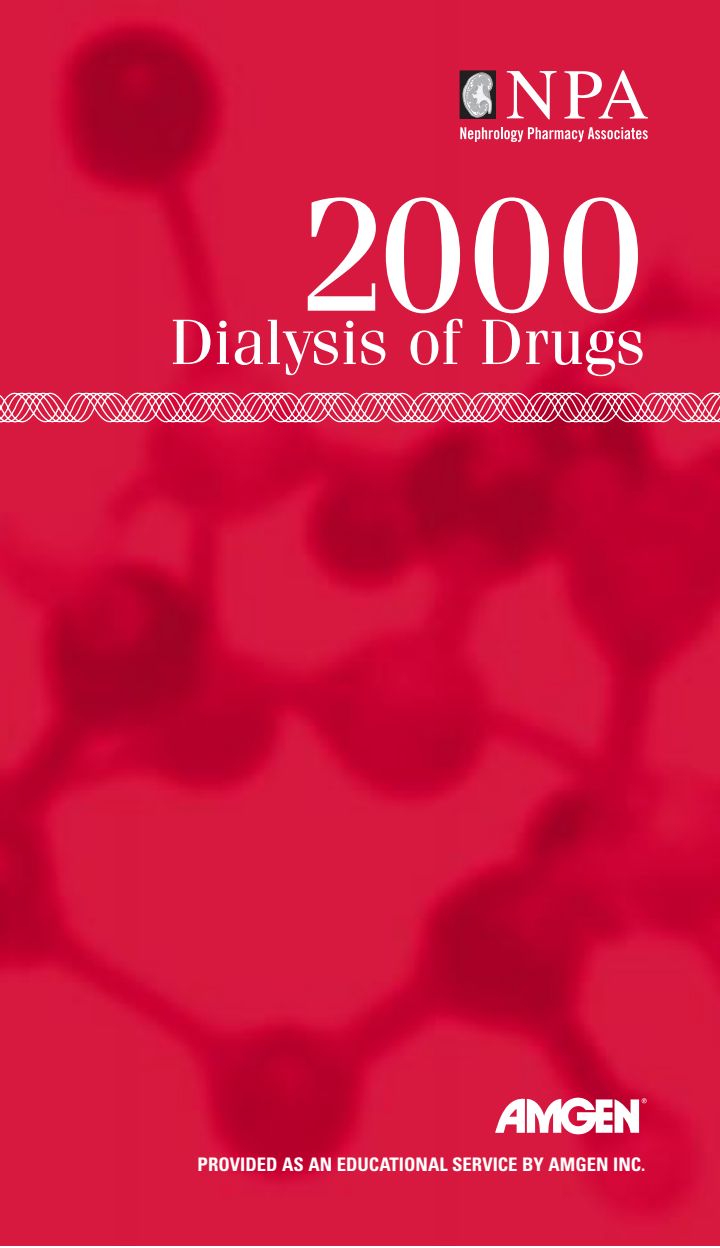
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Dialysis of Drugs
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2000
Dialysis of Drugs

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Preface

Drug removal during dialysis is frequently of interest to those caring for patients receiving hemodialysis or peritoneal dialysis. The extent of drug dialyzability determines whether supplemental dosing is necessary during or following dialysis. The accompanying table has been prepared as a reference regarding the effect either form of dialysis may have on drug clearance. This table should be used as a general guideline.

The drugs included in the table are parent drugs. In some cases, these drugs are converted to pharmacologically active or toxic metabolites for which little dialysis information is known. When available, serum drug measurements may be appropriate for dosing individual patients. In all cases, patients should be monitored for clinical efficacy and toxicity.

What Determines Drug Dialyzability?

The extent to which a drug is affected by dialysis is determined primarily by several physicochemical characteristics of the drug, which are briefly described in the text that follows. These include molecular size, protein binding, volume of distribution, water solubility, and plasma clearance. In addition to these properties of the drug, technical aspects of the dialysis procedure may also determine the extent to which a drug is removed by dialysis.

Molecular Weight

Dialysis is dependent upon the use of a dialytic membrane: either a synthetic membrane with fixed pore size, as in hemodialysis, or a naturally occurring peritoneal membrane, as in peritoneal dialysis. The movement of drugs or other solutes is largely determined by the size of these molecules in relation to the pore size of the membrane. As a general rule, smaller molecular weight substances will pass through the membrane more easily than larger molecular weight substances. A common assumption is that pore size of the peritoneal membrane is somewhat larger than that of the hemodialysis membrane; this would explain the observation that larger molecular weight substances appear to cross the peritoneal membrane to a greater extent than they cross the hemodialysis membrane.

Protein Binding

Another important factor determining drug dialyzability is the concentration gradient of unbound (free) drug across the dialysis membrane. Drugs with a high degree of protein binding will have a small plasma concentration of unbound drug available for dialysis. Uremia may have an effect on protein binding for some drugs. Through mechanisms not completely understood, protein binding may decrease in uremic serum. Should this change in binding be substantial, increased dialyzability of free drug may occur.

Because the primary binding proteins for most drugs (albumin, α_1-acid glycoprotein) are of large molecular size, the drug-protein complex is often too large to cross the dialysis membrane, especially in the case of the hemodialysis membrane. Since the peritoneal membrane does permit the passage of some proteins, there may be some limited drug-protein removal with this technique. Increased protein concentrations have been noted in peritoneal effluent during episodes of peritonitis.

Volume of Distribution

A drug with a large volume of distribution is distributed widely throughout tissues and is present in relatively small amounts in the blood. Factors that contribute to a drug having a large volume of distribution include a high degree of lipid solubility and low plasma protein binding. Drugs with a large volume of distribution are likely to be minimally dialyzed.

Water Solubility

The dialysate used for either hemodialysis or peritoneal dialysis is an aqueous solution. In general, drugs with high water solubility will be dialyzed to a greater extent than those with high lipid solubility. Highly lipid-soluble drugs tend to be distributed throughout tissues, and therefore only a small fraction of the drug is present in plasma and accessible for dialysis.

Plasma Clearance

The inherent metabolic clearance—the sum of renal and nonrenal clearance—of a drug is often termed the "plasma clearance" of a drug. In dialysis patients, renal clearance is largely replaced by dialysate clearance. If, for a particular drug, nonrenal clearance is large compared to renal clearance, the contribution dialysis may make to total drug removal is low. However, if renal (dialysis) clearance increases plasma clearance by 30% or more, dialysis clearance is considered to be clinically important.

Dialysis Membrane

As mentioned previously, the characteristics of the dialysis membrane determine to a large extent the dialysis of drugs. Pore size, surface area, and geometry are the primary determinants of the performance of a given membrane. The technology of hemodialysis continues to evolve, and new membranes continue to be introduced for clinical use. Interpretation of published literature should be tempered with the understanding that newer membranes may have different drug dialysis characteristics. On the other hand, because the peritoneal membrane is natural, little can be done to alter its characteristics.

Blood and Dialysate Flow Rates

The hemodialysis prescription contains a determination of blood and dialysate flow rates. As drugs normally move from blood to dialysate, the flow rates of these two substances may have a pronounced effect on dialyzability. In general, increased blood flow rates during hemodialysis will enable greater amounts of drug to be delivered to the dialysis membrane. As concentrations of drug increase in the dialysate, the flow rate of the dialysis solution also becomes important in overall drug removal. Greater dialysis can be achieved with faster dialysate flow rates that keep dialysate drug concentrations at a minimum.

During peritoneal dialysis, little can be done to alter blood flow rates to the peritoneum. However, dialysate flow rates are determined by the volume and frequency of dialysate exchange in the peritoneum. At low exchange rates, drug concentrations in the dialysate will increase during the period of time in which the dialysate resides in the peritoneal cavity, thus slowing additional movement of drug across the membrane. More frequent exchanges will favor increased drug dialyzability, provided the drug's physicochemical characteristics permit its movement across the peritoneal membrane.

Special Considerations

HIGH PERMEABILITY DIALYSIS

Most of the information contained in this guide has been obtained from studies conducted under conditions of standard hemodialysis that employed conventional dialysis membranes. Recent changes in dialysis technology have led to more permeable dialysis membranes and the opportunity to employ higher blood and dialysate flow rates. These new technolgies are often referred to as “high permeability”, “high-efficiency” and “high-flux” dialysis. The Food and Drug Administration has proposed that high permeability dialysis membranes be defined as those whose in vitro ultrafiltration coefficient (KUf) is above 12 mL/mm Hg/hour (Federal Register, March 15, 1999, pg 12776). Commonly included in this group of dialysis membranes are polysulfone, polyacrylonitrile, and high-efficiency cuprammonium rayon dialyzers. Changes in dialysis membranes and changes in blood and dialysis flow rates may have clinically important effects on drug removal through the membrane.

There are an increasing number of studies to examine the effects of high permeability dialysis on drug dialyzability. Results of these studies have confirmed predictions that drug removal from plasma is often enhanced as compared with more traditional dialysis membranes. This year’s edition of Dialysis of Drugs includes a revised table on dialyzability to incorporate expanding information regard-

ing the removal of drugs during high permeability dialysis. Studies with high permeability dialysis also have demonstrated that removal of drug from plasma often exceeds the transfer of drug from tissues to plasma. As a result, there is often a rebound of plasma drug concentrations following the conclusion of dialysis as blood-tissue drug equilibration occurs. Patients receiving high permeability dialysis may require more drug compared with those receiving standard hemodialysis. Due to the many technical and physiological variables, individualized therapeutic drug monitoring may be necessary. The reader is referred to the primary literature for further details.

CONTINUOUS RENAL REPLACEMENT THERAPY

Another therapeutic development that will affect drug dialyzability is continuous renal replacement therapy (CRRT), known in its various forms as continuous arteriovenous hemofiltration (CAVH), continuous venovenous hemofiltration (CVVH), continuous arteriovenous hemodialysis (CAVHD), continuous venovenous hemodialysis (CVVHD), continuous venovenous hemodiafiltration (CVVHDF), continuous arteriovenous hemodiafiltration (CAVHDF), slow continuous ultrafiltration (SCUF), continuous arteriovenous high-flux hemodialysis (CAVHFD) and continuous venovenous high-flux hemodialysis (CVVHFD). These various techniques are used in the management of acute renal failure in critically ill patients.

Continuous renal replacement therapies differ considerably from intermittent hemodialysis. Relying heavily upon continuous ultrafiltration of plasma water, CRRT has the potential for the removal of large quantities of ultrafilterable drugs contained in the plasma. Unfortunately, few in vivo studies have been published, and very few drugs have been studied pharmacokinetically in intensive care patients. Therefore, many guidelines for drug dosing during CRRT have been extrapolated from experiences with chronic hemodialysis or from theoretical considerations based upon general principles of drug removal derived from the physicochemical characteristics of the drug and the CRRT technique employed.

Molecular weight of a drug has been an important determinant of drug dialyzability in conventional hemodialysis. This drug characteristic becomes less important during CRRT because of the use of high-flux hemofilters that permit passage of larger molecules up to 5000 Da. As is true with conventional hemodialysis, drugs with large volumes of distribution are unlikely to be removed to a great extent during CRRT. Most of the body stores of such drugs are outside the vascular compartment and not accessible to the hemofilter for removal. Similarly, drugs that are highly bound to plasma proteins are not subject to significant removal during CRRT because the molecular weight of drug-protein complexes usually hinders passage of the complex across the filter. The fraction of unbound drug may change during renal failure, however, thus altering the likelihood of drug

removal. If the unbound fraction increases, more drug clearance may occur. If the unbound fraction becomes less, there is likely to be less drug removal during CRRT.

A useful tool to predict the likelihood of a drug to cross the hemofilter membrane is the sieving coefficient. This term is defined as the ratio of drug concentration in the ultrafiltrate to the pre-filter plasma water concentration of the drug. If the sieving coefficient is close to 1.0, the drug has relatively free passage across the filter. The following table presents sieving coefficient data from in vitro and in vivo evaluations.

SIEVING COEFFICIENT

Drug Name	Predicted	Measured	Condition	Filter
Amikacin	0.95	0.88	in vivo	PS[a]
Amphotericin	0.10	0.40	in vivo	PS[a]
Ampicillin	0.80	0.69	in vivo	PS[a]
Cefoperazone	0.10	0.27	in vivo	PS[a]
Cefotaxime	0.62	0.51	in vivo	PS[a]
Cefoxitin	0.30	0.30	in vitro	PS[a]
Ceftazidime	0.90	0.90	in vivo	PS[a]
Ceftriaxone	0.10	0.71	in vivo	PS[a]
Cefuroxime	0.66	0.59	in vivo	PS[a]
Clindamycin	0.40	0.98	in vivo	PS[a]
Digoxin	0.80	0.96	in vivo	PS[a]
		0.35	in vitro	PS[a]
		0.18	in vitro	PS[b]

		1.21	in vitro	AN69[c]
		1.07	in vitro	PA[d]
Erythromycin	0.30	0.37	in vivo	PS[a]
Gentamicin	0.95	0.81	in vivo	PS[a]
Metronidazole	0.80	0.86	in vivo	PS[a]
Mezlocillin	0.68	0.68	in vivo	PS[a]
N-acetylprocainamide	0.90	0.92	in vivo	PS[a]
Nafcillin	0.20	0.54	in vivo	PS[a]
Oxacillin	0.05	0.02	in vivo	PS[a]
Phenobarbital	0.60	0.86	in vivo	PS[a]
Phenytoin	0.10	0.45	in vivo	PS[a]
		0.14	in vitro	PS[a]
		0.12	in vitro	PS[b]
		0.08	in vitro	AN69[c]
		0.17	in vitro	PA[d]
		0.08	in vitro	PS[a]
Procainamide	0.86	0.86	in vivo	PS[a]
Theophylline	0.47	0.85	in vitro	PS[a]
		0.93	in vitro	AN69[c]
		0.78	in vivo	PA[d]
Tobramycin	0.95	0.78	in vivo	PS[a]
		0.90	in vitro	PS[a]
		0.75	in vitro	PS[b]
		0.59	in vitro	AN69[c]

		0.76	in vitro	PA[d]
Valproic acid	0.10	0.18	in vitro	PS[a]
		0.31	in vitro	AN69[c]
		0.16	in vitro	PA[d]
Vancomycin	0.90	0.76	in vivo	PS[a]
		0.60	in vitro	PS[a]
		0.71	in vitro	PS[b]
		0.64	in vitro	AN69[c]
		0.58	in vitro	PA[d]

[a]Amicon diafilter (polysulfone)
[b]Renal System (polysulfone)
[c]Hospal (AN69)
[d]Gambro (polyamide)

The above table was published in the following article: Joy MS, Matzke, GR, Armstrong DK, Marx MA, Zarowitz BJ. A primer on continuous renal replacement therapy for critically ill patients. *Ann Pharmacother.* 1998;32:362- 75. Reprinted with permission. Harvey Whitney Books Company.

The specific CRRT technique employed will influence the ultrafiltration rate and hence, the potential rate of drug removal. When CRRT relies solely on spontaneous blood flow without extracorporeal blood pumping, an ultrafiltration rate of 10-15 mL/min can be anticipated. The addition of blood pumps and continuous dialysis may increase the ultrafiltration rate to 50 mL/min. Higher rates of ultrafiltration may lead to greater drug removal with a need for more frequent replacement doses. Drug removal can be determined by collection of the total volume of dialysate/ultrafiltrate and

measurement of the concentration of drug in the effluent.

Because of the multiple techniques employed in CRRT, the variability in individual patient circumstances, and the lack of in vivo data, the tables in this guide do not contain information on drug removal during CRRT. Once again, the reader is referred to the primary literature for assistance with the dosing of specific drugs.

PLASMAPHERESIS

Plasmapheresis is another special consideration in which drug removal from plasma may be of concern. This technique is being used increasingly for the treatment of certain immunologic, infectious and metabolic diseases, as well as for the removal of toxins that cannot be removed by hemodialysis or peritoneal dialysis. Plasmapheresis removes plasma from the patient with replacement by crystalloid or colloid solutions. Solutes such as drug molecules that are present in the plasma may be removed from the patient. Unfortunately, little is known about the specific pharmacokinetic effects of plasmapheresis. The procedure may be most likely to remove substances that are lipophilic, that are highly protein-bound, and that have a small volume of distribution. The reader is referred to reference 4.

SUMMARY

Drug dialyzability is determined by a complex interaction of many factors, including the characteristics of the drug and the technical aspects of the dialysis system. Published studies on drug dialyzability should specify the conditions that pertain during dialysis. Results from these studies should be applied with caution to other dialysis conditions.

About This Guide

These guidelines have been designed to provide extensive, easy-to-read information regarding the dialyzability of drugs. Numerous literature sources have been used in preparing the guidelines. For many drugs, including newly-approved medications, no studies have been done to determine the effect of dialysis on drug removal. In some cases, the available data may conflict. Conditions of dialysis used in published studies may not necessarily reflect current dialysis procedures and technology. Variations in the duration of dialysis, flow rates, dialysis membranes, and whether peritoneal dialysis is continuous or intermittent will all affect drug removal. This educational review will attempt to distinguish between conventional hemodialysis and high permeability (often called high-flux) hemodialysis where such data are available. However, the review does not contain information on drug dialyzability with CRRT (See "Special Considerations," page 10) or with plasmapheresis. For additional information on specific drugs, the reader should consult the primary literature.

A designation of "Yes" in the Hemodialysis and Peritoneal Dialysis columns indicates that supplemental dosing of a drug is usually required during or following hemodialysis or peritoneal dialysis in order to maintain a therapeutic concentration of the drug in the blood. "No" indicates that such supplementation is not required. As a general principle, usual methods of continuous ambulatory peritoneal

dialysis (CAPD) provide relatively low drug clearances during any given dialysate exchange. However, cumulative drug removal may require dosage supplementation at appropriate intervals. Increased drug dialyzability may occur with increased peritoneal dialysate flow rates or in the presence of peritonitis. A designation of "U" indicates that no dialysis studies have been published but that the authors of this guide have concluded that significant drug removal during dialysis is unlikely based upon the physicochemical characteristics of the drug, which are primarily a high degree of protein binding, a large molecular weight, or a large volume of distribution. A designation of "L" indicates that no published data exist on the removal of the drug during high permeability dialysis. However, the authors have extrapolated data from studies using conventional dialysis to conclude that significant drug removal is likely to occur during high permeability dialysis. A designation of "ND" indicates that no data are available on drug dialyzability. In some cases, the literature reports the use of a high permeability, or high-flux, dialysis membrane, however the type of membrane is not specified. A designation of "NS" indicates membrane type is not specified.

Key

Yes Indicates supplemental dosing in conjunction with dialysis is *usually required*

No Indicates supplemental dosing is *not required*

U Indicates significant drug removal is *unlikely* based on physicochemical characteristics of the drug such as protein binding, molecular size or volume of distribution

L Indicates no published data exist, but information extrapolated from studies using conventional dialysis techniques suggests significant drug removal is *likely* during high permeability dialysis

ND Indicates there are *no data* on drug dialyzability with this type of dialysis

NS Indicates the type of high permeability membrane was *not specified*

* Removed with hemoperfusion

Note: *In these tables,* ***conventional*** *hemodialysis is defined as the use of a dialysis membrane whose in vitro coefficient of ultrafiltration (KUf) ≤ 12 mL/hour/mm Hg. Data also are placed in the conventional column if the literature does not specify the type of dialysis membrane employed.* ***High permeability*** *hemodialysis is defined as the use of a dialysis membrane whose KUf >12 mL/hour/mm Hg. In the high permeability column in the tables, the KUf of the membrane(s) used is included in parentheses.*

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Abacavir	ND	ND	ND
Abciximab	U	ND	U
Acarbose	ND	ND	ND
Acebutolol (diacetolol)	Yes	L	ND
Acetaminophen	Yes	L	No
Acetazolamide	U	ND	No
Acetohexamide	U	ND	U
Acetophenazine	U	ND	U
Acitretin	U	ND	U
Acyclovir	Yes	L	No
Adenosine	U	ND	U
Albendazole	No	ND	U
Albumin	U	ND	U
Albuterol	No	ND	U
Aldeparin	ND	ND	ND
Aldesleukin	ND	ND	ND
Alendronate	No	ND	ND
Alfentanil	U	ND	U
Allopurinol	Yes	L	ND
Alprazolam	No	ND	U
Alprostadil	No	ND	ND
Alteplase	U	ND	U
Amantadine	No	ND	No
Amdinocillin	No	ND	No
Amifostine	ND	ND	ND
Amikacin	Yes	L	Yes

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Amiloride	ND	ND	ND
Aminocaproic acid	Yes	ND	Yes
Aminoglutethimide	Yes	L	ND
Aminosalicylic acid	Yes	L	ND
Amiodarone	No	ND	No
Amitriptyline	No	ND	No
Amlodipine	No	ND	No
Amoxapine	U	ND	U
Amoxicillin	Yes	L	No
Amphotericin B	No	ND	No
Amphotericin B lipid complex	No	ND	U
Ampicillin	Yes	L	No
Amprenavir	U	ND	ND
Amrinone	U	ND	No
Anagrelide	ND	ND	ND
Anastrozole	ND	ND	ND
Anistreplase	U	ND	U
Antithymocyte globulin (ATG)	U	ND	U
Aprotinin	U	ND	U
Arbutamine	ND	ND	ND
Ardeparin	No	ND	ND
Asparaginase	U	ND	U
Aspirin	Yes	L	Yes
Atenolol	Yes	L	No

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Atorvastatin	U	ND	U
Atovaquone	U	ND	U
Atracurium	U	ND	U
Atropine	No	ND	ND
Auranofin	No	ND	ND
Azathioprine	Yes	L	ND
Azithromycin	ND	ND	ND
Azlocillin	Yes	L	No
Aztreonam	Yes	L	No
Baclofen	ND	ND	ND
Basiliximab	U	ND	U
Benazepril (benazeprilat)	No	ND	ND
Benzquinamide	U	ND	NA
Bepridil	No	ND	U
Betamethasone	ND	ND	ND
Betaxolol	No	ND	No
Bethanechol	ND	ND	ND
Bezafibrate	No	ND	No
Biapenem	Yes	L	ND
Bicalutamide	U	ND	U
Bisoprolol	No	ND	ND
Bleomycin	No	ND	No
Bretylium	Yes	L	ND
Bromfenac	No	ND	U
Bromocriptine	U	ND	U

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Buflomedil	No	No (20)	U
Bumetanide	No	ND	U
Bupropion	No	ND	No
Buspirone	No	ND	ND
Busulfan	ND	ND	ND
Butalbital	ND	ND	ND
Butorphanol	U	ND	U
Caffeine	ND	ND	ND
Calcitriol	No	No (31)	U
Candesartan	No	ND	ND
Capecitabine	ND	ND	ND
Capreomycin	Yes	L	ND
Captopril	Yes	L	No
Carbamazepine	No	ND	No
Carbenicillin	Yes	L	No
Carbidopa/levodopa	ND	ND	ND
Carboplatin	Yes	L	ND
Carboprost	ND	ND	ND
Carisoprodol	Yes	L	Yes
Carmustine	No	ND	ND
Carnitine	Yes	L	ND
Carprofen	U	ND	U
Carteolol	ND	ND	ND
Carumonam	Yes	L	ND
Carvedilol	No	ND	ND
Cefaclor	Yes	L	Yes

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Cefadroxil	Yes	L	No
Cefamandole	Yes	L	No
Cefazolin	Yes	L	No
Cefdinir	Yes	L	ND
Cefepime	Yes	L	Yes
Cefixime	No	ND	No
Cefmenoxime	Yes	L	ND
Cefmetazole	Yes	L	No
Cefodizime	No	ND	No
Cefonicid	No	ND	No
Cefoperazone	No	ND	No
Ceforanide	Yes	L	No
Cefotaxime	Yes	L	No
Cefotetan	Yes	L	Yes
Cefoxitin	Yes	L	No
Cefpirome	Yes	Yes (40)	No
Cefpodoxime	Yes	L	No
Cefprozil	Yes	L	ND
Cefroxadine	ND	ND	ND
Cefsulodin	Yes	L	Yes
Ceftazidime	Yes	L	Yes
Ceftibuten	Yes	L	ND
Ceftizoxime	Yes	L	No
Ceftriaxone	No	ND	No
Cefuroxime	Yes	L	No
Celecoxib	U	ND	U

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Cephalexin	Yes	L	No
Cephalothin	Yes	L	No
Cephapirin	Yes	L	No
Cephradine	Yes	L	Yes
Cerivastatin	U	ND	U
Cetirizine	No	ND	U
Chloral hydrate	Yes	L	ND
Chlorambucil	No	ND	No
Chloramphenicol	Yes	L	No
Chlordiazepoxide	No	ND	U
Chloroquine	No	ND	No
Chlorpheniramine	Yes	L	No
Chlorpromazine	No	ND	No
Chlorpropamide	No*	ND	No
Chlorprothixene	U	ND	U
Chlorthalidone	No	ND	U
Cidofovir	ND	Yes (60)	No
Cilastatin	Yes	L	ND
Cilazapril	Yes	L	ND
Cilostazol	U	ND	U
Cimetidine	No	ND	No
Cinoxacin	No	ND	U
Ciprofloxacin	No	ND	No
Cisapride	No	ND	U
Cisatracurium	U	ND	U
Cisplatin	No	ND	ND

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Citalopram	U	ND	U
Cladribine	ND	ND	ND
Clarithromycin	ND	ND	ND
Clavulanic acid	Yes	ND	Yes
Clemastine	ND	ND	ND
Clindamycin	No	ND	No
Clodronate	Yes	ND	No
Clofazimine	No	ND	No
Clofibrate	No	ND	No
Clomipramine	U	ND	U
Clonazepam	No	ND	U
Clonidine	No	ND	No
Clopidogrel	U	ND	U
Clorazepate	No	ND	U
Cloxacillin	No	ND	No
Clozapine	U	ND	U
Codeine	No	ND	U
Colchicine	No	ND	No
Cortisone	No	ND	No
Cyclacillin	Yes	L	No
Cyclophosphamide	Yes	L	ND
Cycloserine	Yes	L	ND
Cyclosporine	No	ND	No
Cysteamine	ND	ND	No
Cytarabine	No	ND	No
Dacarbazine	ND	ND	ND

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Daclizumab	U	ND	U
Dactinomycin	ND	ND	ND
Dalteparin	U	ND	U
Danaparoid	ND	ND	ND
Dapsone	Yes	L	ND
Daunorubicin	ND	ND	ND
Deferoxamine	Yes	L	ND
Deflazacort	No	ND	U
Delavirdine	U	ND	U
Desipramine	No	ND	No
Desmopressin	ND	ND	ND
Dexamethasone	No	ND	No
Dexfenfluramine	ND	ND	ND
Dexrazoxane	ND	ND	ND
Dezocine	ND	ND	ND
Diazepam	No	ND	U
Diazoxide	Yes	L	Yes
Dibekacin	Yes	L	ND
Diclofenac	U	ND	U
Dicloxacillin	No	ND	No
Didanosine	No	ND	No
Diethylpropion	ND	ND	ND
Diflunisal	No	ND	U
Digitoxin	No	ND	No
Digoxin	No	ND	No
Dihydroergotamine	ND	ND	ND

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Diltiazem	No	ND	No
Diphenhydramine	U	ND	U
Diphenoxylate/Atropine	ND	ND	ND
Dipyridamole	U	ND	ND
Dirithromycin	No	ND	No
Disopyramide	Yes	L	ND
Dobutamine	No	ND	No
Docetaxel	U	ND	U
Dolasetron	ND	ND	ND
Donepezil	U	ND	U
Dopamine	No	ND	U
Doxacurium	No	ND	U
Doxazosin	No	ND	No
Doxepin	No	ND	No
Doxercalciferol	No	ND	U
Doxorubicin	No	ND	ND
Doxycycline	No	ND	No
Dronabinol	U	ND	U
Droperidol	U	ND	U
Edetate calcium (EDTA)	Yes	L	Yes
Efavirenz	U	ND	U
Enalapril (enalaprilat)	Yes	L	Yes
Encainide	No	ND	ND
Enoxacin	No	ND	No
Enoxaparin	No	ND	U
Ephedrine	ND	ND	ND

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Epinephrine	ND	ND	ND
Epoetin alfa	No	ND	No
Epoprostenol	ND	ND	ND
Eprosartan	U	No (60)	U
Eptifibatide	ND	ND	ND
Ergocalciferol	ND	ND	ND
Erythromycin	No	ND	No
Esmolol (ASL-8123)	Yes	L	Yes
Estazolam	U	ND	U
Ethacrynic acid	No	ND	U
Ethambutol	No	No (80)	U
Ethchlorvynol	No*	ND	No
Ethinyl estradiol	ND	ND	No
Ethosuximide	Yes	L	ND
Etodolac	No	ND	U
Etoposide	No	ND	No
Famciclovir (penciclovir)	Yes	L	ND
Famotidine	No	ND	No
Felbamate	ND	ND	ND
Felodipine	No	ND	U
Fenfluramine	ND	ND	ND
Fenofibrate	No	ND	U
Fenoldopam	U	ND	No
Fenoprofen	No	ND	U
Fentanyl	ND	ND	ND
Ferric gluconate	No	ND	U

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Ferrous (iron) salts	U	ND	U
Fexofenadine	No	ND	U
Filgrastim	No	ND	U
Finasteride	U	ND	U
Flecainide	No	ND	U
Fleroxacin	No	No (22)	No
Floxuridine	ND	ND	ND
Fluconazole	Yes	L	Yesa
Flucytosine	Yes	L	Yes
Fludarabine	ND	ND	ND
Flumazenil	ND	ND	ND
Fluorouracil	Yes	L	ND
Fluoxetine	No	ND	No
Fluphenazine	U	ND	U
Flurazepam	No	ND	U
Flurbiprofen	ND	ND	No
Flutamide	No	ND	U
Fluvastatin	U	ND	U
Fluvoxamine	U	ND	U
Fomepizole	Yes	L	ND
Foscarnet	Yes	Yes (40, 60)	ND
Fosfomycin	Yes	L	ND
Fosinopril (fosinoprilat)	No	ND	No
Fosphenytoin	U	ND	U
Furosemide	No	ND	U
Fusidic acid	No	ND	No

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Gabapentin	Yes	L	ND
Gadodiamide	Yes	L	No
Gadoversetamide	ND	Yes (NS)	ND
Gallium	ND	ND	ND
Gallopamil	U	ND	U
Ganciclovir	Yes	L	ND
Ganirelix	ND	ND	ND
Gemcitabine	ND	ND	ND
Gemfibrozil	No	ND	No
Gentamicin	Yes	Yes (60)	Yes
Glatiramer	ND	ND	ND
Glimepiride	U	ND	U
Glipizide	U	ND	U
Glucagon	U	ND	U
Glutethimide	No*	ND	No
Glyburide	No	ND	U
Gold sodium thiomalate	No	ND	U
Granisetron	ND	ND	ND
Grepafloxacin	ND	ND	ND
Guanabenz	U	ND	ND
Guanadrel	ND	ND	ND
Guanethidine	ND	ND	ND
Guanfacine	No	ND	No
Halofantrine	ND	ND	ND
Haloperidol	No	ND	No
Heparin	No	ND	No

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Hexobarbital	No	ND	U
Hirudin	No	No (NS)	ND
Hydralazine	No	ND	No
Hydrochlorothiazide	No	ND	U
Hydrocodone	ND	ND	ND
Hydrocortisone	U	ND	U
Hydromorphone	ND	ND	ND
Hydroxychloroquine	ND	ND	ND
Hydroxyurea	No	ND	U
Hydroxyzine	No	ND	No
Ibuprofen	No	ND	U
Ibutilide	ND	ND	ND
Idarubicin	U	ND	U
Ifosfamide	Yes	L	ND
Imipenem	Yes	L	Yes
Imipramine	No	ND	No
Immune globulin(human)	U	ND	U
Indapamide	No	ND	U
Indinavir	ND	ND	ND
Indomethacin	No	ND	U
Insulin	No	ND	No
Interferons	No	ND	No
Iodixanol	Yes	L	ND
Iopromide	Yes	Yes (50)	ND
Irbesartan	No	ND	ND

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Irinotecan (SN-38 metabolite)	U	ND	U
Iron dextran	No	ND	U
Isocarboxazid	ND	ND	ND
Isoniazid	No	No (80)	U
Isoproterenol	ND	ND	ND
Isosorbide dinitrate	No	ND	No
Isosorbide mononitrate	Yes	L	No
Isradipine	No	ND	No
Itraconazole	No	ND	U
Kanamycin	Yes	L	Yes
Ketoconazole	No	ND	No
Ketoprofen	U	ND	U
Ketorolac	U	ND	U
Labetalol	No	ND	No
Lamivudine	No	ND	U
Lamotrigine	No	ND	U
Lansoprazole	No	ND	U
Leflunomide	No	ND	No
Letrozole	ND	ND	ND
Leuprolide	ND	ND	ND
Levamisole	ND	ND	ND
Levobupivacaine	U	ND	U
Levofloxacin	U	ND	U
Levonorgestrel	U	ND	U
Levorphanol	ND	ND	ND

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Levothyroxine	U	ND	U
Lidocaine	No	ND	U
Lincomycin	No	ND	No
Lisinopril	Yes	L	ND
Lithium	Yes	L	Yes
Lomefloxacin	No	ND	No
Lomustine	No	ND	U
Loperamide	ND	ND	ND
Loracarbef	Yes	L	ND
Loratadine	No	ND	No
Lorazepam	No	ND	U
Losartan	No	ND	No
Lovastatin	U	ND	U
Loxapine	ND	ND	ND
Mangafodipir	ND	ND	ND
Mannitol	Yes	L	Yes
Maprotiline	No	ND	U
Mechlorethamine	No	ND	No
Meclofenamate	U	ND	U
Mefenamic acid	No	ND	U
Mefloquine	U	ND	U
Melphalan	No	ND	ND
Meperidine	No	ND	U
Meprobamate	Yes	L	Yes
Mercaptopurine	Yes	L	ND
Meropenem	Yes	L	ND

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Mesalamine (5-ASA)	U	ND	U
Mesna	ND	ND	ND
Mesoridazine	U	ND	U
Metaproterenol	ND	ND	ND
Metformin	Yes	L	ND
Methadone	No	ND	No
Methaqualone	No	ND	No
Methenamine	ND	ND	ND
Methicillin	No	ND	No
Methimazole	No	ND	No
Methotrexate	Yes	Yes (60)	No
Methyldopa	Yes	L	Yes
Methylphenidate	U	ND	U
Methylprednisolone	Yes	L	ND
Metoclopramide	No	ND	No
Metolazone	No	ND	U
Metoprolol	Yes	L	ND
Metronidazole	Yes	L	No
Mexiletine	Yes	L	No
Mezlocillin	Yes	L	No
Miacalcin	ND	ND	ND
Miconazole	No	ND	No
Midazolam	No	ND	U
Midodrine (de-glymidodrine)	Yes	ND	NA
Miglitol	ND	ND	ND

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Milrinone	ND	ND	ND
Minocycline	No	ND	No
Minoxidil	Yes	L	Yes
Mirtazapine	U	ND	U
Misoprostol	U	ND	U
Mitomycin	ND	ND	ND
Mitoxantrone	No	ND	No
Mivacurium	ND	ND	ND
Modafinil	ND	ND	ND
Moexipril	ND	ND	ND
Molindone	U	ND	U
Montelukast	U	ND	U
Moricizine	U	ND	U
Morphine	Yes	ND	No
Muromonab-CD3	U	ND	U
Mycophenolate (mycophenolic acid)	No	ND	No
Nabumetone	No	ND	ND
Nadolol	Yes	L	ND
Nafcillin	No	ND	No
Nalmefene	No	ND	U
Naloxone	ND	ND	ND
Naltrexone	ND	ND	ND
Naproxen	No	ND	U
Naratriptan	ND	ND	ND
Nefazodone	U	ND	U

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Nelfinavir	U	ND	U
Netilmicin	Yes	L	Yes
Nevirapine	ND	ND	ND
Nicardipine	No	ND	U
Nicotine	ND	ND	ND
Nicotinic acid	ND	ND	ND
Nifedipine	No	ND	No
Nilutamide	ND	ND	ND
Nimodipine	No	ND	No
Nisoldipine	No	ND	No
Nitrendipine	No	ND	U
Nitrofurantoin	Yes	L	ND
Nitroglycerin	No	ND	No
Nitroprusside	Yes	L	Yes
Nizatidine	No	ND	No
Nomifensine	ND	ND	ND
Norethindrone	ND	ND	No
Norfloxacin	No	ND	U
Nortriptyline	No	ND	No
Octreotide	Yes	L	ND
Ofloxacin	Yes	ND	No
Olanzapine	No	ND	No
Olsalazine	U	ND	U
Omapatrilat	No	ND	ND
Omeprazole	U	ND	U
Ondansetron	U	ND	U

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Orbofiban	Yes	L	ND
Orlistat	U	ND	U
Ornidazole	Yes	L	No
Orphenadrine	ND	ND	ND
Oxacillin	No	ND	No
Oxaprozin	No	ND	U
Oxazepam	No	ND	U
Oxybutynin	ND	ND	ND
Oxycodone	ND	ND	ND
Oxymorphone	ND	ND	ND
Paclitaxel	No	ND	U
Pamidronate	ND	ND	ND
Pancuronium	ND	ND	ND
Pantoprazole	No	ND	ND
Paricalcitol	No	ND	ND
Paroxetine	No	ND	U
Pefloxacin	No	ND	No
Pegaspargase	U	ND	U
Pemoline	Yes	L	No
Penbutolol	No	ND	No
Penicillamine	Yes	L	ND
Pencillin G	Yes	L	No
Pentamidine	No	ND	No
Pentazocine	Yes	L	ND
Pentobarbital	No	ND	U
Pentosan polysulfate	ND	ND	ND

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Pentostatin	ND	ND	ND
Pentoxifylline	U	ND	ND
Pergolide	U	ND	U
Perindopril (perindoprilat)	Yes	L	ND
Perphenazine	U	ND	U
Phenelzine	ND	ND	ND
Phenobarbital	Yes	L	Yes
Phentermine	ND	ND	ND
Phentolamine	ND	ND	ND
Phenylbutazone	No	ND	U
Phenylpropanolamine	ND	ND	ND
Phenytoin	No	Yes (36)	No
Pimagedine (aminoguanidine)	Yes	ND	ND
Pimozide	ND	ND	ND
Pindolol	ND	ND	ND
Pioglitazone	U	ND	U
Piperacillin	Yes	L	No
Piroxicam	U	ND	U
Plicamycin	ND	ND	ND
Polythiazide	No	ND	No
Pralidoxime	ND	ND	ND
Pramipexole	No	ND	U
Pravastatin	No	ND	ND
Prazepam	No	ND	U

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Prazosin	No	ND	No
Prednisone	No	ND	No
Primidone	Yes	L	ND
Probucol	No	ND	No
Procainamide/N-acetyl procainamide (NAPA)	Yes/Yes	L/L	No/No
Procarbazine	ND	ND	ND
Prochlorperazine	U	ND	U
Promazine	U	ND	U
Promethazine	No	ND	ND
Propafenone	No	ND	No
Propofol	U	ND	U
Propoxyphene	No	ND	No
Propranolol	No	ND	No
Protriptyline	No	ND	No
Pseudoephedrine	No	ND	U
Pyrazinamide	Yes	Yes (80)	No
Pyrimethamine	ND	ND	ND
Quazepam	U	ND	U
Quetiapine	ND	ND	ND
Quinapril (quinaprilat)	No	ND	No
Quinidine	No*	ND	No
Quinine	No	ND	No
Quinupristin/dalfopristin	ND	ND	No
Rabeprazole	U	ND	U
Raloxifene	U	ND	U

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Ramipril (ramiprilat)	No	ND	ND
Ranitidine	No	ND	No
Recainam	No	ND	U
Repaglinide	U	ND	U
Reserpine	No	ND	No
Reteplase	ND	ND	ND
Reviparin	No	ND	U
Rifabutin	U	ND	U
Rifampin	No	No (80)	No
Rifapentine	U	ND	U
Rilmenidine	No	ND	U
Rimantadine	No	ND	U
Risperidone	ND	ND	ND
Ritodrine	Yes	L	Yes
Ritonavir	U	ND	U
Rizatriptan	ND	ND	ND
Rocuronium	ND	ND	ND
Rofecoxib	No	ND	U
Ropinirole	U	ND	U
Rosiglitazone	No	ND	U
Roxithromycin	ND	ND	No
Rufloxacin	ND	ND	ND
Salsalate	Yes	L	No
Saquinavir	U	ND	U
Sargramostim	ND	ND	ND
Secobarbital	No	ND	No

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Selegiline	ND	ND	ND
Sermorelin	ND	ND	ND
Sertindole	No	ND	ND
Sertraline	No	ND	U
Sevelamer	U	U	U
Sibutramine	U	ND	U
Sildenafil	U	ND	U
Silver	No	ND	U
Simvastatin	U	ND	U
Sirolimus	U	ND	ND
Sisomicin	Yes	L	ND
Somatropin	U	ND	U
Sotalol	Yes	L	ND
Sparfloxacin	ND	ND	ND
Spectinomycin	Yes	L	Yes
Spirapril (spiraprilat)	U	ND	U
Spironolactone	U	ND	U
Stavudine	ND	ND	ND
Streptomycin	Yes	L	Yes
Streptozocin	ND	ND	ND
Sucralfate	No	ND	No
Sufentanil	U	ND	U
Sulbactam	Yes	L	No
Sulfamethoxazole	Yes	L	No
Sulfisoxazole	Yes	L	Yes
Sulindac	No	ND	U

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Sumatriptan	ND	ND	ND
Tacrine	ND	ND	ND
Tacrolimus	No	ND	U
Tamoxifen	ND	ND	ND
Tamsulosin	U	ND	U
Tazobactam	Yes	L	No
Teicoplanin	No	ND	No
Telmisartan	U	ND	U
Temazepam	No	ND	U
Temocillin	Yes	L	No
Teniposide	U	ND	U
Terazosin	No	ND	No
Terbinafine	U	ND	U
Terbutaline	ND	ND	ND
Testosterone	U	ND	U
Tetracycline	No	ND	No
Thalidomide	ND	ND	ND
Theophylline	Yes	L	No
Thiethylperazine	ND	ND	ND
Thioguanine	ND	ND	ND
Thioridazine	U	ND	U
Thiotepa	ND	ND	ND
Thiothixene	U	ND	U
Tiagabine	No	ND	ND
Ticarcillin	Yes	L	No
Ticlopidine	U	ND	U

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Tiludronate	U	ND	U
Timolol	No	ND	No
Tinidazole	Yes	L	ND
Tirofiban	Yes	L	ND
Tizanidine	ND	ND	ND
Tobramycin	Yes	L	Yes
Tocainide	Yes	L	ND
Tolazamide	U	ND	U
Tolbutamide	No	ND	U
Tolcapone	U	ND	ND
Tolmetin	U	ND	U
Tolterodine	U	ND	U
Topiramate	Yes	L	ND
Topotecan	ND	ND	ND
Torsemide	No	ND	U
Tramadol	No	ND	U
Trandolapril (trandolaprilat)	Yes	L	ND
Tranexamic acid	ND	ND	ND
Tranylcypromine	ND	ND	ND
Trapidil	ND	ND	ND
Trazodone	U	ND	U
Tretinoin	ND	ND	ND
Triamterene	ND	ND	ND
Triazolam	No	ND	U
Trifluoperazine	No	ND	No

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH PERMEABILITY (KUf)	
Triflupromazine	U	ND	U
Trihexyphenidyl	ND	ND	ND
Trimethoprim	Yes	L	No
Trimetrexate	U	ND	U
Trimipramine	U	ND	U
Troglitazone	U	ND	U
Tropisetron	U	ND	U
Trovafloxacin	No	ND	ND
Ursodiol	U	ND	U
Valacyclovir	Yes	L	ND
Valproic acid	No	ND	No
Valsartan	U	ND	U
Vancomycin	No	Yes (22, 40, 60)	No
Vecuronium	U	ND	U
Venlafaxine	No	ND	U
Verapamil	No	ND	No
Vigabatrin	Yes	L	ND
Vinblastine	ND	ND	ND
Vincristine	ND	ND	ND
Warfarin	No	ND	No
Zafirlukast	U	ND	U
Zalcitabine	ND	ND	ND
Zidovudine/GZDV	No/Yes	ND/L	No/Yes
Zileuton	No	ND	U
Zolmitriptan	ND	ND	ND
Zolpidem	No	ND	U

Drugs of Abuse

DRUG	HEMODIALYSIS		PERITONEAL DIALYSIS
	CONVENTIONAL	HIGH FLUX	
Amphetamine	NA		NA
Cocaine	No		U
Ethanol	Yes		NA
Heroin	U		U
Lysergide (LSD)	U		U
Marijuana (THC)	U		U
Mescaline (peyote)	U		U
Phencyclidine (PCP)	U		U
Psilocybin	NA		NA

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Notes

Notes

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