

Antiseizure Medications and Renal Dysfunction

Authors: Nicole Woodrich, PharmD, Sara Eyal, PhD, FAES, Leonel Estofan, MD, Heidi Henninger, MD, FAAN, Armin Jewell, DO

INTRODUCTION

The table below summarizes current labeling and literature on the antiseizure medication (ASM) treatment of patients with impaired renal function. The table is updated to April 2026. It is aimed at helping clinicians who provide care for persons with epilepsy in adjusting treatment for those with mild, moderate, and severe renal disease. The dosing recommendations refer to adults. The table is followed by figures that summarize the changes in exposure to ASMs in patients with impaired renal function and major physicochemical and pharmacokinetic characteristics that affect the dialysability of ASMs.

BACKGROUND

Renal dysfunction primarily affects the pharmacokinetics of ASMs, which are mostly or exclusively excreted by the kidneys. However, it can also alter drug metabolism and protein binding, thereby affecting “hepatic” drugs. Patients with impaired renal function should be closely monitored for seizure activity and for adverse reactions of ASMs.

TARGET AUDIENCE

The American Epilepsy Society Treatments Committee provides this document for neurologists, pharmacists, nurses, and other specialists who treat persons with epilepsy and for basic scientists who are interested in the hepatic effects of ASMs.

IMPORTANT NOTES

- This document summarizes prescribing and literature data and is not intended to constitute treatment recommendations.
- Recommended ASMs for patients with renal dysfunction include brivaracetam, lacosamide (neither in patients with end-stage renal disease treated with renal replacement therapies), cannabidiol, carbamazepine, clobazam, ethosuximide, lamotrigine, and rufinamide. ¹ Among the benzodiazepines for initial treatment of convulsive status epilepticus, lorazepam is a reasonable first-line choice for patients with end-stage renal disease. The use of diazepam is less recommended in these patients. ²
- Special caution is required in patients with impaired renal function when ASMs are combined with inhibitors of non-renal elimination pathways, such as cytochrome P450 and UDP-glucuronosyltransferases.
- Data were not available for prolonged intermittent renal replacement therapy (PIRRT). PIRRT features elements of both intermittent hemodialysis and continuous renal replacement therapy,³ and dosing may rely on approximations based on the available data.

Antiseizure Medications and Renal Dysfunction Chart



Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
Adrenocortico-tropic hormone (ACTH; corticotropin)					
No recommendation for dose adjustment but use with caution. Monitor for elevated blood pressure and salt/water retention. ⁴⁻⁶			No data, unlikely to be removed	No data, unlikely to be removed	No data, unlikely to be removed
Large molecular weight and high protein binding. Peptides generally not dialyzable unless small/unbound.					
Brivaracetam					
Dose adjustments not required. ⁷			Not recommended. Data not available. ⁷		
1.21-fold increase in AUC in patients with severe renal impairment ^{7,8} (Figure 1).					
Cannabidiol					
Dose adjustments not required. ^{9,10}			Caution recommended A carefully titrated, short-term regimen was generally tolerated. ¹¹	Data not available	Data not available
1.56-fold increase in cannabidiol AUC in patients with severe renal impairment ¹² (Figure 1). Limited potential of being removed by dialysis ^{13,14} (Figure 2).					
Carbamazepine					
Dose adjustments not required. ¹⁵			Variable clearance in overdose settings, but unlikely to require supplemental maintenance doses. ¹⁶⁻¹⁹	No data, unlikely to be considerably removed.	Case reports, may have some removal (greater for carbamazepine epoxide than carbamazepine). ²⁰⁻²²
AUCR in patients with moderate renal impairment 1.04 ^{15,23} (Figure 1). Hepatic metabolism is the primary route of elimination, minimal renal excretion, ^{24,25} not easily displaced from protein binding ²⁰ (Figure 2).					

Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
Cenobamate					
Dose: Use with caution; dosage reduction may be considered. ²⁶ According to EMA, the maximum recommended dose is 300 mg/day. ²⁷		Dose: Dosage reduction may be considered, but an unexpected decrease in exposure was observed in patients with severe renal function. ²⁸ According to EMA, the maximum recommended dose is 300 mg/day, and cenobamate should not be used in patients with ESRD. ²⁷	Not recommended Should not be used in patients with ESRD or patients undergoing hemodialysis. ^{26,28}	Not recommended Data not available. ²⁶	Data not available
AUCR in patients with mild, moderate, and severe renal impairment, 1.37, 1.48, and 0.88, respectively (Figure 1). ²⁸ Likely to be removed by dialysis (Figure 2).					
Clobazam					
Dose adjustment not required. ²⁹		Caution required TDM of total clobazam/norclobazam might underestimate the unbound concentrations. ²⁴ No trials conducted. In a case report, ESRD (CLCr <10 mL/min) did not affect clobazam and norclobazam serum concentrations. ³⁰	Dialytic removal likely low. No trials conducted. In a case report, hemodialysis did not affect clobazam and norclobazam serum concentrations. ³⁰	Data not available	Data not available
AUCR of clobazam in patients with mild and moderate renal impairment, 1.13 and 1.10, respectively. Respective AUCR of norclobazam 1.36 and 1.13. ³¹ Highly lipophilic and extensively protein bound (Figure 2).					
Clonazepam					
Likely dose adjustment not required ²⁴			Data not available.	Data not available	Data not available
Active drug not excreted by the kidneys. ²⁴ Unlikely to be considerably removed by dialysis (Figure 2)					

Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
Eslicarbazepine acetate					
Dose adjustment not required ³²	Dose: CLCr < 50 mL/min: Initial titration and maintenance dosages should generally be reduced by 50%. ³³		Repeated hemodialysis removes eslicarbazepine's metabolites (beginning second dialysis). ^{32,34,35}	No data. Caution required; use low initial doses. ³⁵	No data; likely to be removed by CRRT. ³⁵
Renal clearance correlated with creatinine clearance. ³³ AUCR in patients with mild, moderate, and severe renal impairment, 1.61, 2.11, and 2.54, respectively ³⁴ (Figure 1).					
Ethosuximide					
Dose adjustment not required. ²⁹		Caution required; Dose: Use low initial doses. ³⁵	The majority removed by hemodialysis; Supplemental doses likely to be required. ²⁴	A case report describes removal of 50% of the daily dose by peritoneal dialysis. ³⁶	No data; likely to be significantly removed. ³⁵
Likely to be removed by dialysis (Figure 2).					
Everolimus					
Dose adjustment not required ³⁷			Data not available.	Data not available	Data not available
AUCR in patients with CLCr 30 to 80 mL/min, 10 to 30 mL/min, and 5 to 10 mL/min, 1.63, 1.72, and 2.13, respectively ³⁹ (Figure 1). Likely to be removed by dialysis (Figure 2).					
Fenfluramine					
Dose adjustment not required/slower titration eGFR 60 to 90 mL/min/1.73m ² : No change. ⁴⁰ Consider a slower titration. If adverse reactions are reported, a dose reduction may be needed. ⁴¹	Dose adjustment not required/slower titration eGFR 30 to 60 mL/min/1.73m ² : No change. ⁴⁰ Consider a slower titration. If adverse reactions are reported, a dose reduction may be needed. ⁴¹	Dose: eGFR 15 to 29 mL/min/1.73m ² : Max dose 20 mg/day without stiripentol. Max dose 17 mg/day with stiripentol + clobazam. Consider slower titration in patients with eGFR < 15 mL/min/1.73m ² . ⁴⁰ Not studied in patients with ESRD. ⁴⁰	Data not available. ⁴¹		Data not available
50% protein binding, high volume of distribution. AUCR of fenfluramine and norfenfluramine in patients with eGFR < 30 mL/min/1.73m ² , 1.88 and 1.21, respectively ⁴⁰ (Figure 1).					

Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
Gabapentin					
Dose: CLCr > 60 mL/min: 900 to 3,600 mg/day, split into three times per day dosing ^{24,42,43}	Dose: CLCr 30 to 59 mL/min: 400 to 1,400 mg/day dosing, split into twice daily dosing ^{24,42,43} Patients with moderate renal dysfunction had an increase in AUC of >160%.	Dose: CLCr 15 to 29 mL/min: 200 to 700 mg oncedaily dosing ^{24,42,43} CLCr <15 mL/min: daily dose in should be reduced in proportion to creatinine clearance (e.g., when CLCr = 7.5 mL/min, half the dose given to patients with CLCr 15 mL/min. ⁴³	Daily dose based on CLCr + post-hemodialysis Supplemental Dose (daily dose values refer to normal renal function dose): 125 mg (900 mg/day) 150 mg (1200 mg/day) 200 mg (1800 mg/day) 250 mg (for 2400 mg/day) 350 mg (3600 mg/day). ⁴³ Approximately 35% of the dose recovered in dialysate. ⁴⁴	No consensus recommendation. Proposed protocols: Dosing as in patients with CLCr <15 mL/min ³⁵ Or 100 mg every other day with titration to effect up to 300 mg every other day.	No consensus recommendation. Proposed protocols: Initiate dosing as in patients with CLCr 15-50 mL/min ³⁵ Or Initial: 100 mg twice daily and titrate to effect. Suggested maximum dose: 300 mg twice daily.
Total clearance and renal clearance are linearly related to the creatinine clearance. ⁴² In a setting of overdose, peritoneal dialysis led to a shortened half-life of gabapentin. ⁴⁵ However, clearance by peritoneal dialysis is slower than in hemodialysis. AUCR in patients with CLCr 30 to 59 mL/min and < 30 mL/min, 2.92 and 6.67, respectively ⁴² (Figure 1). Highly likely to be removed by dialysis (Figure 2).					
Ganaxolone					
Likely dose adjustment not required/Dose: No data; likely no adjustment necessary (minimal excretion of ganaxolone by kidneys). ⁴⁶ According to EMA, can be administered to patients with mild, moderate, or severe renal impairment without dose adjustment. ⁴⁷			Data not available.	Data not available.	Data not available.
Unlikely to be removed by dialysis (Figure 2). AUCR in patients with CLCr 15 to 30 mL/min, 0.92 ⁴⁷ (Figure 1).					
Lacosamide					
Likely dose adjustment not required eGFR 60 to 89 mL/min/1.73 m ² : usually no adjustment; Dose initiation and titration should be based on clinical response and tolerability. ⁴⁸ Monitor for CNS effects, ECG, and symptoms of AV block (the latter particularly in	Likely dose adjustment not required/caution required eGFR 30 to 59 mL/min/1.73 m ² : often no initial adjustment but use clinical judgement and monitoring. Dose initiation and titration should be based on clinical response and tolerability. ⁴⁸ Monitor for CNS effects, ECG,	Dose: eGFR <30 mL/min/1.73 m ² : reduce dose; label recommends max 300 mg/day. ⁴⁸ Dose initiation and titration should be based on clinical response and tolerability. ⁴⁸ In severe impairment/ESRD, consider ECG monitoring for PR prolongation. ³⁵	Dosage supplementation of up to 50% should be considered. ⁴⁸ Dialyzable (~50% in 4-hr hemodialysis). ⁴⁹	Data not available	CRRT increases clearance and requires individualization. ⁵⁰

Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
patients at risk of cardiac disorders or on concomitant medications that prolong the PR-interval). ³⁵	and symptoms of AV block (the latter particularly in patients at risk of cardiac disorders or on concomitant medications that prolong the PR-interval). ³⁵				
Dose reduction may be necessary in patients with impaired renal function who are concomitantly treated with strong inhibitors of CYP3A4 and CYP2C9. ¹ AUCR in patients with CLCr ≥ 50 to 80 mL/min, ≥ 30 to 50 mL/min, and <20 to 30 mL/min (no dialysis ≥ 2 weeks), 1.27, 1.22, and 1.59, respectively ⁴⁹ (Figure 1). Dialyzable (Figure 2).					
Lamotrigine					
Likely dose adjustment not required No routine adjustment; Initial doses should be based on concomitant medications. ⁵¹ Monitor clinical response and interactions that affect glucuronidation. Monitor for dermatological reactions, ³⁵ particularly in the first 6 months of lamotrigine treatment.	Likely dose adjustment not required/caution required No routine adjustment, but use with caution; initial doses should be based on concomitant medications. ⁵¹ Reduced maintenance doses may be effective for patients with significant renal impairment. ²⁴ Monitor clinical response and interactions that affect glucuronidation. Monitor for dermatological reactions, ³⁵ particularly in the first 6 months of treatment.	Dosing usually unchanged but monitor clinically. ²⁴ Not significantly removed (approximately 20%) ⁵¹	Data not available.	Data not available.	
AUCR in patients with CLCr 10.6 to 25.5 mL/min, 1.01 ⁵² (Figure 1). The main metabolite, lamotrigine 2-N-glucuronide, is excreted by the kidneys and may accumulate in patients with severe renal impairment. ⁵² Intermediate lipophilicity and volume of distribution as compared to other ASMs; plasma protein binding 56%.					
Levetiracetam					
Dose: eGFR > 80 mL/min/1.73 m ² : 500 to 1,500 mg every 12 hr eGFR 60 to 80 mL/min/1.73 m ² : 500 to 1,000 mg every 12 hr. Monitor clinically, with attention to behavioral and	Dose: eGFR 50 to 60 mL/min/1.73 m ² : 500 to 1,000 mg every 12 hr eGFR 30 to 50 mL/min/1.73 m ² : 250 to 750 mg every 12 hr. ⁵³ Monitor clinically, with	Dose: eGFR <30 mL/min/1.73 m ² : follow label dosing (e.g. 250–500 mg every 12 hr) or extend interval. ⁵³ Monitor clinically, with attention to behavioral and psychiatric changes. ^{35,53}	500 to 1,000 mg every 24 hr. Give supplemental dose after hemodialysis (commonly 250–500 mg). ⁵³ Monitor for breakthrough seizures. ^{50,53} Dialyzable (~50% removed in 4-hr hemodialysis). ^{54,55}	Data not available.	Consider 750–1000 mg every 12 h. ²⁰ Monitor. ^{53,56} Clearance similar to adults with normal renal function;

Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
psychiatric changes. ^{35,53}	attention to behavioral and psychiatric changes. ^{35,53} Consider monitoring levels. ⁵³				
AUCR in patients with CLCr 50 to 80 mL/min, 30 to 50 mL/min, and < 30 mL/min, 1.7, 2.5, and 3.0, respectively ⁵⁵ (Figure 1). Loading doses for acute seizure control usually unchanged; maintenance dosing should be adjusted for renal function. Low molecular weight, lipophilicity, and protein binding; clearance proportional to GFR.					
Oxcarbazepine					
Likely dose adjustment not required CLCr > 30 mL/min: Usually no change to initial dosing. ^{1,24,57} Monitor sodium ⁵⁸	Likely dose adjustment not required CLCr 30 to 59: Usually no change to initial dosing. ^{1,24,57} Monitor sodium ⁵⁸	Dose: CLCr <30 mL/min: initiate at one-half the usual starting dose (300 mg/day every 12 hr), and increase slowly to achieve the desired clinical response. ^{1,24,57} Monitor sodium ⁵⁸ Marked reduction in clearance. ³⁵	Supplemental dosing after hemodialysis may be required; monitor drug levels. ⁵⁰ Monitor sodium ⁵⁸ In patients with ESRD on dialysis, it is recommended that immediate-release oxcarbazepine be used instead of controlled-release preparations. ⁵⁹	Data not available.	Data not available.
Prodrug metabolized to the active 10-monohydroxy derivative (MHD, licarbazepine); primarily renally excreted as glucuronide and unchanged metabolite. ⁵⁷ Linear correlation between creatinine clearance and the renal clearance of MHD. ⁵⁷ AUCR of MHD in patients with CLCr 30 to 80 mL/min and 10 to 30 mL/min, 1.66 and 2.33, respectively ⁶⁰ (Figure 1). MHD is dialyzable due to relatively low protein binding and volume of distribution.					
Perampanel					
Likely dose adjustment not required ^{61,62} Monitor for behavioral and psychiatric changes. ³⁵ CLCr 50 to 80 mL/min: 27% decrease in CL/F with 37% increase in AUC, but overlap in values with patients with normal renal function (a population pharmacokinetic study). ⁶²	Dose: May need dose adjustment. Slower titration may be considered; Close monitoring recommended, particularly for behavioral and psychiatric changes. ^{35,62} CLCr 30–50 mL/min (3 patients): 14% lower CL/F than patient with normal renal function.	Not recommended ⁶³	According to the FDA product information, use if patients undergoing hemodialysis is not recommended. ⁶² Limited data. 1% change in C/D ratio post-dialysis vs. pre-dialysis. ⁵⁴	Data not available.	Data not available.
In patients with CLCr of 39 to 160 mL/min, perampanel clearance was not affected by CLCr. ⁶¹ Unlikely to be removed by dialysis (Figure 2).					

Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
Phenobarbital					
Dose adjustment not required ^{1,24} Chronic use should generally be avoided. ¹		Dose: May require a dose reduction with GFR < 10 mL/min. Decrease dosage by increasing the dosing interval. Adjust dose based on response and serum concentrations. Chronic use should generally be avoided. ¹ Some drug accumulation may occur. ⁶⁴	Pre- and postdialysis monitoring of serum levels can help in dosing individualization. ⁶⁴ It is better to administer the supplementary dose after hemodialysis. ¹ 20-50% removed in a 4- hr session (depending on efficiency and flow) ⁶⁴⁻⁶⁷	Supplemental dose likely needed but no consistent recommendation for dose adjustment. ¹ Pre- and postdialysis monitoring of serum levels can help in dosing individualization. ⁶⁴	No initial dose adjustment. ²⁰ Monitor and adjust dose accordingly. ²⁰ Significant removal may occur, but extent varies with CRRT settings (effluent flow rate, filter type). ⁶⁸⁻⁷¹
35-50% removed in continuous cycling peritoneal dialysis and ambulatory sessions. ⁷²⁻⁷⁵ In case reports, systemic elimination during CRRT was 5-7.5-fold higher than at baseline. ^{68,71}					
Phenytoin and fosphenytoin					
Dose: In patients with renal disease, the monitoring of unbound phenytoin concentrations may be more relevant. Patients with a history of renal disease should not receive the oral loading regimen. ^{76,77} Suggested dosage adjustment: If CLCr is >10 mL/min, dosage adjustment is not necessary. If CLCr is <10 mL/min, dosage adjustment and monitoring of serum concentrations are required. ¹ After IV fosphenytoin administration to patients with renal disease, fosphenytoin clearance to phenytoin may be increased without a similar increase in phenytoin clearance. This has the potential to increase the frequency and severity of adverse events. ⁷⁷ The phosphate load provided by fosphenytoin (0.0037 mmol phosphate/mg Cerebyx®) should be considered when treating patients with severe renal impairment. ⁷⁷			Supplemental dosing after dialysis is controversial. ^{1,78} Phenytoin is not significantly removed during a standard hemodialysis session.	Supplemental dosing after dialysis is controversial. ^{1,78} Phenytoin is not significantly removed during a standard peritoneal dialysis session.	No initial dose adjustment, ²⁰ but higher daily doses may be needed. ⁷⁹ Monitor free phenytoin. ²⁰ Continuous hemofiltration may remove a clinically significant amount of phenytoin. ⁷⁹
A revised equation has been suggested for calculating phenytoin free concentrations in patients with ESRD. ⁸⁰ AUCR of fosphenytoin and phenytoin in ESRD patients (CLCr < 5 mL/min; fosphenytoin administered 4 hr after end of dialysis), 0.55 and 0.93, respectively ⁸¹ (Figure 1). Intermediate lipophilicity; high protein binding.					
Pregabalin					
Dose adjustment not required CLCr > 60 mL/min ⁸²	Dose: CLCr 30 to 60 mL/min: Reduce dose in half; dosing twice to three times daily. ^{82,83}	Dose: CLCr 15-30 mL/min: Reduce dose by ~66-75% and dose daily to twice daily. ^{82,83} End-stage renal disease (CLCr: <15 mL/min): Reduce dose by ~90% and dose once daily. ^{82,83}	Adjust the pregabalin daily dose based on renal function. In addition to the daily dose adjustment, administer a supplemental dose immediately following every 4-hr hemodialysis treatment.	No data outside of low dose in uremic pruritus. ⁸⁴	25 to 50 mg oral (immediate release), every 8 hr. ⁵⁰

Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
			Patients on 25 mg/day: one supplemental 25 mg or 50 mg dose. 25 to 50 mg/day: one supplemental 50 mg or 75 mg dose. 50 to 75 mg/day: one supplemental 75 mg or 100 mg dose. 75 mg/day: take one supplemental 100 mg or 150 mg dose.⁸²		
AUCR in patients with CLCr 30 to 50 mL/min and < 30 mL/min not requiring dialysis (compared with CLCr >60 mL/min), 1.77 and 3.29⁸³, respectively (Figure 1). Likely to be removed by dialysis (Figure 2). Following a 4-hr hemodialysis, plasma concentrations are reduced by ~ 50-60%.^{83,85}					
Primidone					
Dose: CLCr >50 mL/min: give the usual dose every 12 hr.^{1,86}	Dose: CLCr >50 mL/min: give the usual dose every 12 hr CLCr 10 to 50 mL/min: give the usual dose every 8 to 24 hr.^{1,86}	Dose: CLCr 10 to 50 mL/min: give the usual dose every 8 to 24 hr CLCr < 10 mL/min: give the dose every 12 to 24 hr; adjust dosing based on treatment response and serum levels.^{1,86}	A supplemental dose of one-third of the routine dose after the hemodialysis session has been suggested.¹ Primidone is partially removed by hemodialysis, but the PEMA concentrations were reported to be above normal.⁸⁷	Data not available	Data not available
One of primidone's active metabolites, PEMA, is eliminated only by renal excretion and its renal clearance is correlated significantly with CLCr.⁸⁸ Generally, the use of primidone is not recommended in patients with renal dysfunction.¹ PEMA may accumulate during dialysis. Patients with renal impairment treated with primidone should be evaluated periodically for drug toxicity and PEMA accumulation.⁸⁹ Cases of intoxication with high PEMA concentrations have been reported in patients with moderate to severe renal dysfunction.^{89,90}					
Rufinamide					
Dose adjustment not required^{1,91}		Dose adjustment not required^{1,91} Rufinamide pharmacokinetics in patients with severe renal impairment (creatinine clearance < 30 mL/min) were similar to that of healthy subjects.⁹²	Adjusting the dose for the loss of rufinamide during hemodialysis should be considered.^{1,91} Dialysis 3 times a week 3 h after dosing was predicted to reduce the average AUC by 12% to 26% compared with no dialysis.⁹³	Data not available	Data not available

Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
AUCR in patients with CLCr < 30 mL/min 0.92 ⁹³ (Figure 1). Low protein binding, intermediate lipophilicity and volume of distribution as compared to other ASM					
Stiripentol					
Not recommended According to EMA, stiripentol is not recommended for patients with impaired renal function. ⁹⁴	Not recommended Administration to patients with moderate or severe renal impairment is not recommended. ⁹⁵		Data not available.	Data not available	Data not available
Stiripentol metabolites are eliminated mainly through the kidneys. ⁹⁵ Removal by dialysis is unlikely (Figure 2). A study on the PK of stiripentol (NCT05735951) in patients with renal impairment was completed in Nov 30 2024.					
Tiagabine					
Likely dose adjustment not required ^{1,96,97} Dosage should be adjusted according to patient's response and adverse reactions. ¹			Likely dose adjustment not required ⁹⁶ No difference in pharmacokinetic parameters between hemodialysis and normal renal function. ⁹⁶	No data, likely no adjustment needed ⁹⁸	No data, likely no adjustment needed ⁹⁸
AUCR in patients with CLCr 40 to 80 mL/min and 20 to 39 mL/min (multiple doses), 1.35 and 1.11, respectively ⁹⁶ (Figure 1). Removal by dialysis or CRRT is unlikely (Figure 2).					
Topiramate					
Dose adjustment not required/Dose: CLCr > 70 mL/min/1.73 m ² Dose adjustment not required. CLCr < 70 mL/min/1.73 m ² : Reduce dose by 50% and slowly titrate. ⁹⁹ Overall exposure (AUC _{0-∞}) higher in mild—moderate (85%) renal impairment. ¹⁰⁰	Dose: Reduce dose by 50% and slowly titrate. ⁹⁹ Overall exposure (AUC _{0-∞}) was higher in mild—moderate (85%) renal impairment. ¹⁰⁰	Dose: Reduce dose by 50% and slowly titrate. ⁹⁹ Overall exposure (AUC _{0-∞}) was higher in severe renal impairment (117%). ¹⁰⁰	A supplemental dose of 50% of the daily dose should be given after each session. ¹⁶ Hemodialysis effectively removes topiramate (dialysis clearance ~4-12-fold greater than oral clearance, ^{99,100} ~50% of the drug is removed). ¹⁶ The supplemental dose should consider the dialysis duration, clearance of the dialysis system, and	Data not available. ⁹⁸	Likely need normal renal function dosing or more. ¹⁰¹

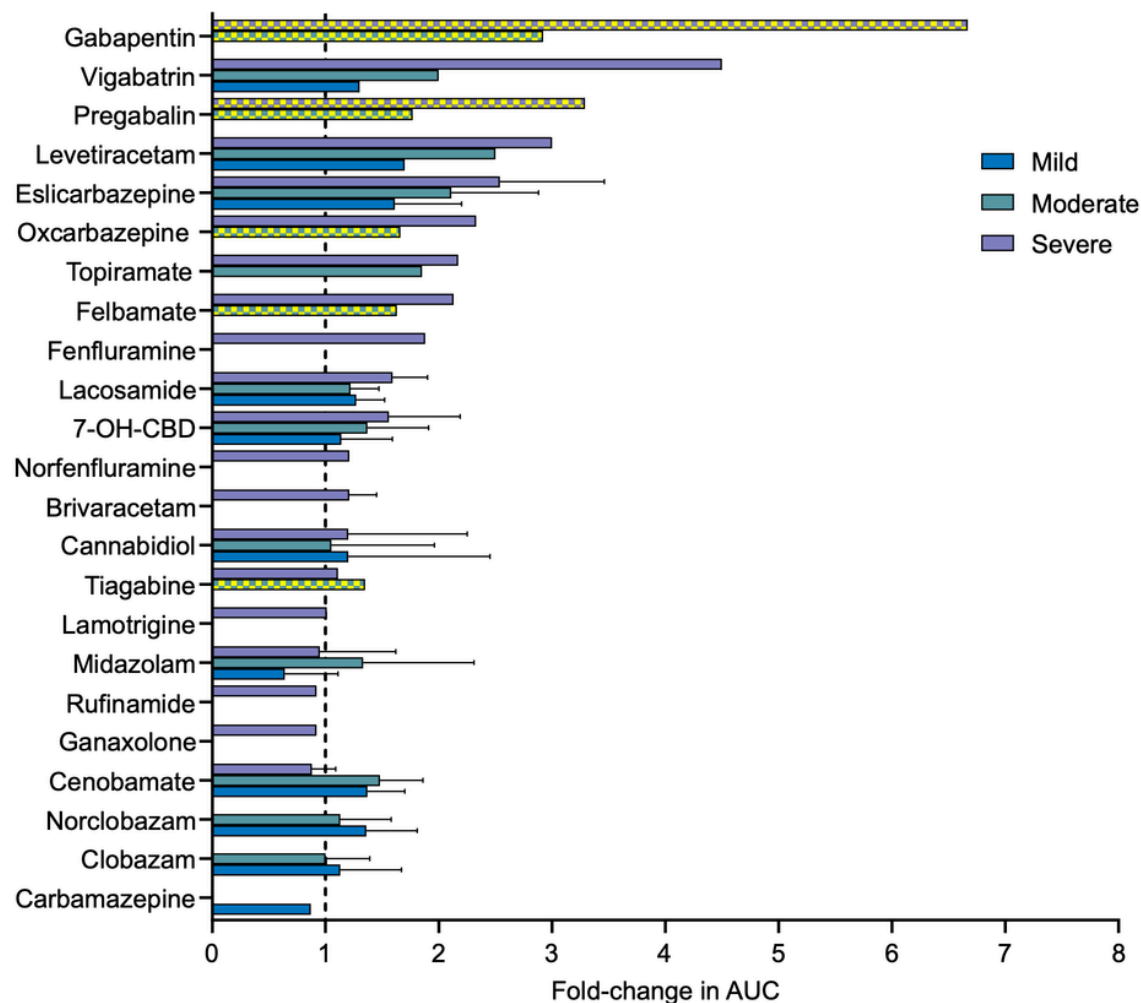
Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
			topiramate effective renal clearance in the patient. ⁹⁹		
When in conjunction with EASMs, hepatic metabolism becomes the main determinant of clearance – so less of a dose adjustment is needed for kidney disease.¹⁰⁰ Severe respiratory disorders, status epilepticus, diarrhea, ketogenic diet, or specific drugs increase the risk of acidosis in patients with renal dysfunction treated with topiramate.⁹⁹ AUCR in patients with CrCr 30 to 69 mL/min/1.73 m² and CrCr < 30 mL/min/1.73 m², 1.85 and 2.17, respectively¹⁰⁰ (Figure 1). Removal by dialysis is likely (Figure 2).⁹⁸					
Valproic acid and its derivatives: (valproic acid, sodium valproate, and divalproex sodium)					
Likely dose adjustment not required.¹⁰² Close monitoring of valproate serum concentration may be warranted,¹ but monitoring total concentrations may be misleading.¹⁰²			Consider a supplemental dose after hemodialysis in some patients.¹ Concentrations are typically reduced by about 20%.¹⁰²	In a uremic child, peritoneal dialysis for 12 or 24 h removed an average of 4.5% of the valproate dose.¹⁰³	Monitor free valproic acid level, if possible.²⁰ In a patient with status epilepticus, clinically significant amounts of valproate were removed by CRRT.¹⁰⁴
Removal from plasma by dialysis or CRRT may be enhanced due to increased unbound fraction. ²⁰					
Valproic acid and its derivatives: (valproic acid, sodium valproate, and divalproex sodium)					
Likely dose adjustment not required.¹⁰² Close monitoring of valproate serum concentration may be warranted,¹ but monitoring total concentrations may be misleading.¹⁰²			Consider a supplemental dose after hemodialysis in some patients.¹ Concentrations are typically reduced by about 20%.¹⁰²	In a uremic child, peritoneal dialysis for 12 or 24 h removed an average of 4.5% of the valproate dose.¹⁰³	Monitor free valproic acid level, if possible.²⁰ In a patient with status epilepticus, clinically significant amounts of valproate were removed by CRRT.¹⁰⁴
		A slight reduction (27%) in the unbound clearance of valproate has been reported in patients with renal failure (creatinine clearance < 10 mL/minute).¹⁰²			
Removal from plasma by dialysis or CRRT may be enhanced due to increased unbound fraction. ²⁰					

Mild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
Vigabatrin					
Dose: CLCr >50 to 80 mL/min: reduce dose by 25%. ¹⁰⁵	Dose: CLCr >50 to 80 mL/min: reduce dose by 25% CLCr >30 to 50 mL/min): reduce dose by 50%. ¹⁰⁵	Dose: CLCr >10 to 30 mL/min: reduce dose by 75%. ¹⁰⁵	Case reports suggest that vigabatrin should preferentially be administered after dialysis. ¹⁰⁶ Hemodialysis reduced vigabatrin plasma concentrations by 40% to 60%. ¹⁰⁵	Data not available.	Data not available.
AUCR in patients with CLCr >50 to 80 mL/min, >30 to 50 mL/min, and >10 to 30 mL/min, 1.30, 2.0, and 4.5, respectively ¹⁰⁵ (Figure 1). Highly likely to be removed by dialysis (Figure 2).					
Zonisamide					
Dose: Patients might require slower titration and more frequent monitoring. ¹⁰⁷	Dose: GFR > 50 mL/min: Slower titration and more frequent monitoring. ¹⁰⁷ The FDA labeling recommends to avoid using in patients with an estimated GFR < 50 mL/min. Insufficient experience concerning drug dosing and toxicity. ¹⁰⁷		The usual dosage may be prescribed after hemodialysis. ¹ If seizures occur after hemodialysis, a supplemental daily dose may be prescribed in the morning. ¹⁰⁸ Plasma concentrations were reduced by ~ 50% during a 4.5 hr dialysis. ¹⁰⁸	Data not available.	Data not available.
Severe respiratory disorders, status epilepticus, diarrhea, ketogenic diet, or specific drugs increase the risk of acidosis in patients with renal dysfunction treated with zonisamide. ¹⁰⁷ AUCR in patients with CLCr < 20 mL/min, 1.35 ¹⁰⁹ (Figure 1). Likely to be removed by dialysis (Figure 2).					
Diazepam					
Dose: If possible, consider lorazepam as an alternative ² Dosage may be reduced to the smallest effective amount. ¹¹⁰	Avoid, if possible. Some patients with ESRD tolerate diazepam. ² If used, dosage may be reduced to the smallest effective amount. ¹¹⁰	Avoid, if possible. Consider lorazepam as an alternative benzodiazepine. Some patients with ESRD tolerate diazepam. ²			
Minimal renal excretion of diazepam and its active metabolites. However, desmethyl diazepam may accumulate due to increased unbound fraction. ² Diazepam is not effectively removed by dialysis, due to high protein binding and lipophilicity. ¹¹¹ In one study, clearance in patients undergoing hemodialysis was higher than in healthy volunteers, but the change was not statistically significant. ¹¹²					

Miild Renal Impairment	Moderate Renal Impairment	Severe Renal Impairment	Intermittent Hemodialysis	Peritoneal Dialysis	CRRT (Continuous Renal Replacement Therapy)
Lorazepam					
Use with caution No significant pharmacokinetic effect expected, ²⁴ but greater sensitivity (e.g., sedation), especially in the elderly, cannot be ruled out. ¹¹³	Use with caution No significant pharmacokinetic effect expected, ²⁴ but greater sensitivity (e.g., sedation), especially of the elderly, cannot be ruled out. ¹¹³	No need for an additional dose to maintain therapeutic concentrations. Only 8 % removed during 6 h of hemodialysis. ²⁴	Data not available.	Use with caution. No consensus recommendation available. The fraction of lorazepam removed by CVVH is negligible compared with its metabolic clearances. ¹¹⁴	
Highly protein bound and extensively metabolized (Figure 2). ²⁰					
Midazolam					
Caution in patients with chronic renal failure. Dose: Elimination of midazolam may be delayed and the effects prolonged. ¹¹⁵	Caution in patients with chronic renal failure. Dose – ¹¹⁵ Monitoring recommended. Possibly prolonged sedation due to accumulation of conjugated metabolites. ¹¹⁶ Reduced clearance and prolonged half-life in acute renal failure. ¹¹⁷	One study reported 6-fold higher AUC after intravenous administration in hemodialysis patients compared with healthy controls. ¹¹⁸ Others found no change ¹¹⁹ or reduced ¹²⁰ exposure to midazolam that was administered orally.	Exposure to intravenous midazolam was 75% of that in controls. Exposure to 1-OH midazolam increased by 16%. ¹¹⁸	Titration to effect recommended. The fraction of midazolam removed by CVVH is negligible compared with its metabolic clearance. ^{20,118} The metabolite 1-hydroxymidazolam glucuronide is effectively removed by CVVH, potentially preventing the prolonged sedation seen in untreated patients with renal failure. ¹¹⁴	
60% reduction in the AUC of oral midazolam before dialysis compared to healthy individuals. The relationship between metabolite levels and prolonged sedation is unclear. ¹¹⁷ AUCR in patients with eGFR 61.0 to 78.8 mL/min/1.73 m ² , 30.5 to 56.0 mL/min/1.73 m ² , 9.4 to 27.5 mL/min/1.73 m ² , 6.00 to 15.0 mL/min/1.73 m ² (mixed population), and 15 mL/min/1.73 m ² (Chinese population), 0.64, ¹¹⁹ 1.33, ¹¹⁹ 0.95, ¹¹⁹ 0.40, ¹¹⁹ and 0.28 ¹²⁰ (Figure 1).					

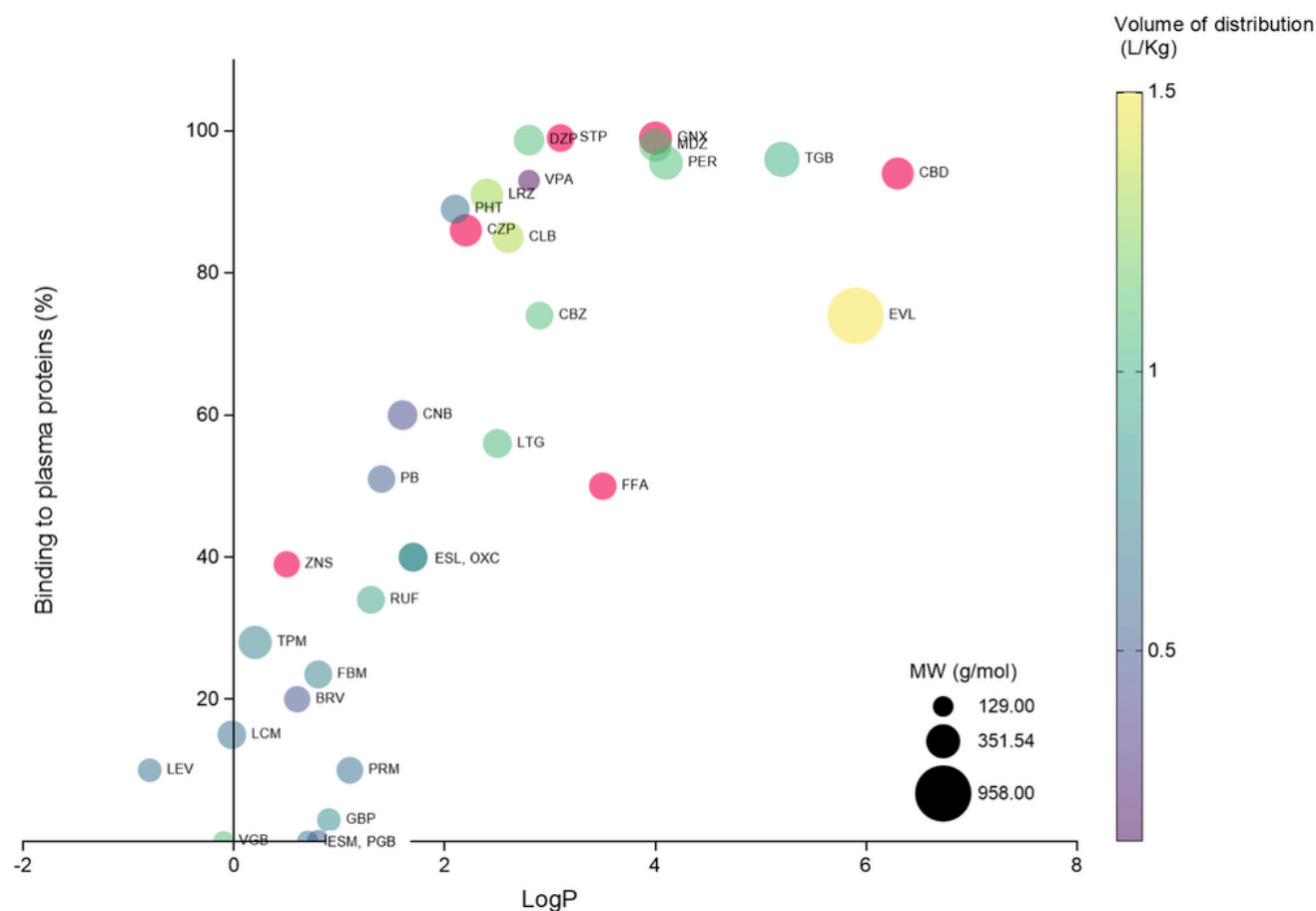
^a95% confidence interval. ASM, antiseizure medication. AUCR, ratio of AUC values in the presence of renal dysfunction/normal renal function. CAPD, continuous ambulatory peritoneal dialysis; CmaxR, ratio of Cmax values in the presence of renal dysfunction/normal renal function; CVVH, continuous venovenous hemofiltration; eGFR, estimated glomerular filtration rate; EIASMs, enzyme-inducing ASMs. EMA, European Medicines Agency; ESRD, end-stage renal disease; PEMA, phenylethylmalonamide.

Figure 1. Effect of Renal Dysfunction on Exposure to Antiseizure Medications.



Change in exposure is expressed as the ratio of the area under the concentration-time curve of the antiseizure medication in the absence or presence of impaired renal function. Values are shown as geometric mean ratios with 90% confidence intervals (error lines; 95% for eslicarbazepine) or ratio of the means (no error lines). Patterned bars represent a potential underestimation of the magnitude of change due to comparisons to control groups that include or consist entirely of patients with mild renal dysfunction. A ratio of 1 (vertical line) indicates no change in exposure. The data for oxcarbazepine refer to its active metabolite, licarbazepine. Also shown are the active metabolites of cannabidiol (7-OH-CBD), clobazam (norclobazam), and fenfluramine (norfenfluramine). When both $AUC_{0-\infty}$ and AUC_{0-last} measurement were available, the default was $AUC_{0-\infty}$.

Figure 2. Physicochemical and Pharmacokinetic Characteristics of Antiseizure Medications that Affect their Dialysability Potential.



Drugs with lower molecular weights, lipophilicity, protein binding, and volume of distribution values are removed more efficiently by dialysis. For example, the ASMs in the upper right quarter are less likely to be removed by dialysis than those in the lower left quarter. Note that the highest value of the volume of distribution on the scale is 1.6 L/Kg. The volumes of distribution of cannabidiol, clonazepam, fenfluramine, ganaxolone, and stiripentol (32.7, 2.6, 11.9, 8.3, 3.2 L/Kg, respectively) are represented by the same color. Corticotropin is not shown. LogP is the logarithm of the octanol-water partition coefficient (a measure of lipophilicity). BRV, brivaracetam; CBD, cannabidiol; CBZ, carbamazepine; CLB, clobazam; CNB, cenobamate; CZP, clonazepam; DZP, diazepam; ESL, eslicarbazepine acetate (data refer to eslicarbazepine); ESM, ethosuximide; EVL, everolimus; FBM, felbamate; FFA, fenfluramine; GBP, gabapentin; GNX, ganaxolone; LCM, lacosamide; LEV, levetiracetam; LTG, lamotrigine; LRZ, lorazepam; MDZ, midazolam; OXC, oxcarbazepine (data refer to licarbazepine); PB, phenobarbital; PER, perampanel; PGB, pregabalin; PHT, phenytoin; PRM, primidone; RUF, rufinamide; STP, stiripentol; TGB, tiagabine; TPM, topiramate; VPA, valproic acid; VGB, vigabatrin; ZNS, zonisamide.

REFERENCES FOR FIGURE 1

- Brivaracetam: FDA. USA Food and Drug Administration. Briviact (brivaracetam). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/205836s017,205837s014,205838s015lbl.pdf. Revised Aug 28, 2025. Accessed Mar 18, 2026. Sargentini-Maier ML, Sokalski A, Boulanger P, Jacobs T, Stockis A. Brivaracetam disposition in renal impairment. *J Clin Pharmacol*. 2012;52(12):1927-1933.
- Cannabidiol: Tayo B, Taylor L, Sahebkar F, Morrison G. A Phase I, Open-Label, Parallel-Group, Single-Dose Trial of the Pharmacokinetics, Safety, and Tolerability of Cannabidiol in Subjects with Mild to Severe Renal Impairment. *Clin Pharmacokinet*. 2020;59(6):747-755.
- Carbamazepine: FDA. Center for Drug Evaluation and Research. Application Number: 206030Orig1s000. Clinical Pharmacology and Biopharmaceutics Review(s). Carbella (carbamazepine). www.accessdata.fda.gov/drugsatfda_docs/nda/2016/206030Orig1s000ClinPharmR.pdf. Date of Review Jun 25, 2014. Accessed January 9, 2026. Ravis W, Tolbert D, Karim A, Cloyd JC. Pharmacokinetics of Carbamazepine in Patients by Renal Function Status: IV Carbamazepine Formulation as a Short-Term Switch from Oral Carbamazepine. <https://aesnet.org/abstractslisting/pharmacokinetics-of-carbamazepine-in-patients-by-renal-function-status-iv-carbamazepine-formulation-as-a-short-term-switch-from-oral-carbamazepine>. Accessed Apr 8, 2026. AES; 3 December, 2016, 2016; Houston, Texas, USA.
- Cenobamate: FDA. Center for Drug Evaluation and Research. Application Number: 212839Orig1s000. Clinical Pharmacology and Biopharmaceutics Review(s). Xcopri (cenobamate). https://www.accessdata.fda.gov/drugsatfda_docs/nda/2019/212839Orig1s000ClinPharmR.pdf. Updated Nov 21, 2019. Accessed Mar 18, 2026.
- Clobazam: FDA. Center for Drug Evaluation and Research. Application Number: 202067Orig1s000. Clinical Pharmacology and Biopharmaceutics Review(s). Onfi (clobazam). https://www.accessdata.fda.gov/drugsatfda_docs/nda/2011/202067Orig1s000ClinPharmR.pdf. Updated Apr 11, 2011. Accessed Nov 7, 2023. 2011.
- Eslicarbazepine acetate: Maia J, Almeida L, Falcão A, et al. Effect of renal impairment on the pharmacokinetics of eslicarbazepine acetate. *Int J Clin Pharmacol Ther*. 2008;46(3):119-130.
- Felbamate: Glue P, Sulowicz W, Colucci R, et al. Single-dose pharmacokinetics of felbamate in patients with renal dysfunction. *Br J Clin Pharmacol*. 1997;44(1):91-93.
- Fenfluramine: Glue P, Sulowicz W, Colucci R, et al. Single-dose pharmacokinetics of felbamate in patients with renal dysfunction. *Br J Clin Pharmacol*. 1997;44(1):91-93.
- Gabapentin: Blum RA, Comstock TJ, Sica DA, et al. Pharmacokinetics of gabapentin in subjects with various degrees of renal function. *Clin Pharmacol Ther*. 1994;56(2):154-159.
- Ganaxolone: EMA. European Medicines Agency. Summary of product characteristics. Ztalmu (ganaxolone): EPAR - Product Information. Updated Jan 15, 2026. Accessed Mar 18, 2026.
- Lacosamide: Cawello W, Fuhr U, Hering U, Maatouk H, Halabi A. Impact of impaired renal function on the pharmacokinetics of the antiepileptic drug lacosamide. *Clin Pharmacokinet*. 2013;52(10):897-906.
- Lamotrigine: Wootton R, Soul-Lawton J, Rolan PE, Sheung CT, Cooper JD, Posner J. Comparison of the pharmacokinetics of lamotrigine in patients with chronic renal failure and healthy volunteers. *Br J Clin Pharmacol*. 1997;43(1):23-27.
- Levetiracetam: FDA. Center for Drug Evaluation and Research. Application Number: 206030Orig1s000. Clinical Pharmacology and Biopharmaceutics Review(s). Keppra (levetiracetam). https://www.accessdata.fda.gov/drugsatfda_docs/nda/99/21035_Keppra_biopharmr_P1.pdf. Date of Review Nov 30, 1999. Accessed Mar 28, 2026. 1999.
- Oxcarbazepine: Rouan MC, Lecaillon JB, Godbillon J, et al. The effect of renal impairment on the pharmacokinetics of oxcarbazepine and its metabolites. *Eur J Clin Pharmacol*. 1994;47(2):161-167.
- Fosphenytoin: Aweeka FT, Gottwald MD, Gambertoglio JG, et al. Pharmacokinetics of fosphenytoin in patients with hepatic or renal disease. *Epilepsia*. 1999;40(6):777-782.
- Pregabalin: Randinitis EJ, Posvar EL, Alvey CW, Sedman AJ, Cook JA, Bockbrader HN. Pharmacokinetics of pregabalin in subjects with various degrees of renal function. *J Clin Pharmacol*. 2003;43(3):277-283.
- Rufinamide: Perucca E, Cloyd J, Critchley D, Fuseau E. Rufinamide: clinical pharmacokinetics and concentration-response relationships in patients with epilepsy. *Epilepsia*. 2008;49(7):1123-1141.
- Tiagabine: Cato A, 3rd, Gustavson LE, Qian J, El-Shourbagy T, Kelly EA. Effect of renal impairment on the pharmacokinetics and tolerability of tiagabine. *Epilepsia*. 1998;39(1):43-47.
- Topiramate: Manitsipitkul P, Curtin CR, Shalayda K, Wang SS, Ford L, Heald DL. Pharmacokinetics of topiramate in patients with renal impairment, end-stage renal disease undergoing hemodialysis, or hepatic impairment. *Epilepsy Res*. 2014;108(5):891-901.
- Vigabatrin: FDA. USA Food and Drug Administration. Sabril (vigabatrin). https://www.accessdata.fda.gov/drugsatfda_docs/label/2021/020427s025,022006s026lbl.pdf. Revised Oct 20, 2021. Accessed Apr 3, 2026.
- Zonisamide: FDA. USA Food and Drug Administration. Zonergan (Zonisamide). https://www.accessdata.fda.gov/drugsatfda_docs/label/2020/020789s036lbl.pdf. Revised Apr 13, 2020. Accessed Jun 26, 2026.
- Midazolam: Tatossian DA, Yee KL, Zhang Z, et al. A Microdose Cocktail to Evaluate Drug Interactions in Patients with Renal Impairment. *Clin Pharmacol Ther*. 2021;109(2):403-415. Kong W, Pan Y, Wu Y, et al. Microdose Cocktail Study Reveals the Activity and Key Influencing Factors of OATP1B, P-Gp, BCRP, and CYP3A in End-Stage Renal Disease Patients. *Clin Pharmacol Ther*. 2025;117(5):1303-1312

REFERENCES FOR FIGURE 2

Anderson, GD, Hakimian, S., 2014. Pharmacokinetic of antiepileptic drugs in patients with hepatic or renal impairment. *Clin Pharmacokinet* 53, 29-49; Borgå O, Hoppel C, Odar-Cederlöf I, Garle M. Plasma levels and renal excretion of phenytoin and its metabolites in patients with renal failure. *Clin Pharmacol Ther.* 1979 Sep;26(3):306-14. doi: 10.1002/cpt1979263306. PMID: 466924; Dinis-Oliveira RJ. Metabolic profile of oxazepam and related benzodiazepines: clinical and forensic aspects. *Drug Metab Rev.* 2017 Nov;49(4):451-463. doi: 10.1080/03602532.2017.1377223. Epub 2017 Sep 14. PMID: 28903606; EMA product information; FDA product information; Gören MZ, Onat F. Ethosuximide: from bench to bedside. *CNS Drug Rev.* 2007 Summer;13(2):224-39. doi: 10.1111/j.1527-3458.2007.00009.x. PMID: 17627674; PMCID: PMC6528725; Hartinger JM, Ryšánek P, Slanař O, Šíma M. Pharmacokinetic principles of dose adjustment of mTOR inhibitors in solid organ transplanted patients. *J Clin Pharm Ther.* 2022 Sep;47(9):1362-1367. doi: 10.1111/jcpt.13753. Epub 2022 Aug 7. PMID: 35934622; Levy RH, Lin HS, Blehaut HM, Tor JA. Pharmacokinetics of stiripentol in normal man: evidence of nonlinearity. *J Clin Pharmacol.* 1983 Nov-Dec;23(11-12):523-33. doi: 10.1002/j.1552-4604.1983.tb01799.x. PMID: 6662977; Martines C, Gatti G, Sasso E, Calzetti S, Perucca E. The disposition of primidone in elderly patients. *Br J Clin Pharmacol.* 1990 Oct;30(4):607-11. doi: 10.1111/j.1365-2125.1990.tb03820.x. PMID: 2291873; PMCID: PMC1368252; Odi, R., Bibi, D., Wager, T., Bialer, M., 2020. A perspective on the physicochemical and biopharmaceutic properties of marketed antiseizure drugs-From phenobarbital to cenobamate and beyond. *Epilepsia* 61, 1543-1552. For ACTH and everolimus, PubChem; Patsalos, P., 2022. *Antiepileptic Drug Interactions: A Clinical Guide*, 4 ed. Springer Cham, Cham, Switzerland.

Ragueneau-Majlessi, I., Yu, J., Isoherranen, N., 2023. Design and Optimization of Dosage Regimens: Pharmacokinetic Data, in: Brunton, L.L., Knollmann, B.C. (Eds); Trinko E. Phenobarbital in Status epilepticus - Rediscovery of an effective drug. *Epilepsy Behav.* 2023 Apr;141:109104. doi: 10.1016/j.yebeh.2023.109104. Epub 2023 Feb 18. PMID: 36807987; Tolbert D, Larsen F. A Comprehensive Overview of the Clinical Pharmacokinetics of Clobazam. *J Clin Pharmacol.* 2019 Jan;59(1):7-19. doi: 10.1002/jcph.1313. Epub 2018 Oct 4. PMID: 30285275; PMCID: PMC6585772; Yeung CHT, Beers JL, Jackson KD, Edginton AN. Verifying in vitro-determined enzyme contributions to cannabidiol clearance for exposure predictions in human through physiologically-based pharmacokinetic modeling. *CPT Pharmacometrics Syst Pharmacol.* 2023 Mar;12(3):320-332. doi: 10.1002/psp4.12908. Epub 2023 Jan 8. PMID: 36540909; PMCID: PMC10014054.

REFERENCES

1. Asadi-Pooya AA, Sperling MR. Antiseizure Medications. A Clinician's Manual. 3rd ed. Oxford: Oxford University Press; 2023.
2. Wilcock A, Charlesworth S, Twycross R, et al. Prescribing Non-Opioid Drugs in End-Stage Kidney Disease. *J Pain Symptom Manage.* 2017;54(5):776-787.
3. Clark EG, Vijayan A. How I prescribe prolonged intermittent renal replacement therapy. *Crit Care.* 2023;27(1):88.
4. FDA. U.S. Food & Drug Administration. Drug Approvals and Databases. Acthar Gel (corticotropin). https://www.accessdata.fda.gov/drugsatfda_docs/label/2024/008372s074lbl.pdf. Revised Apr Feb 29, 2024. Accessed Jun 28, 2026.
5. Poola N, Due B, Wright D, Brooks LR, Zaman F. Pharmacokinetics and Pharmacodynamics of Repository Corticotropin Injection Compared With Synthetic ACTH(1-24) Depot and Methylprednisolone in Healthy Subjects. *Clin Pharmacol Drug Dev.* 2022;11(4):502-515.
6. Wan GJ, Niewoehner J, Hayes K. Acthar Gel (RCI): A Narrative Literature Review of Clinical and Economic Evidence. *Clinicoecon Outcomes Res.* 2023;15:499-512.
7. FDA. USA Food and Drug Administration. Briviact (brivaracetam). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/205836s017,205837s014,205838s015lbl.pdf. Revised Aug 28, 2025. Accessed May 12, 2026.
8. Sargentini-Maier ML, Sokalski A, Boulanger P, Jacobs T, Stockis A. Brivaracetam disposition in renal impairment. *J Clin Pharmacol.* 2012;52(12):1927-1933.
9. EMA. European Medicines Agency. Summary of product characteristics. Epidyolex (cannabidiol). https://www.ema.europa.eu/en/documents/product-information/epidyolex-epar-product-information_en.pdf. Updated Feb 27, 2026. Accessed Apr 2, 2026.
10. FDA. USA Food and Drug Administration. https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/210365s023lbl.pdf. Epidiolex (cannabidiol). Updated Jun 26, 2025. Accessed May 12, 2026.
11. Kliuk-Ben Bassat O, Schechter M, Ashtamker N, et al. Medical cannabis for pain management in patients undergoing chronic hemodialysis: randomized, double-blind, cross-over, feasibility study. *Clin Kidney J.* 2023;16(4):701-710.
12. Tayo B, Taylor L, Sahebkar F, Morrison G. A Phase I, Open-Label, Parallel-Group, Single-Dose Trial of the Pharmacokinetics, Safety, and Tolerability of Cannabidiol in Subjects with Mild to Severe Renal Impairment. *Clin Pharmacokinet.* 2020;59(6):747-755.

13. Bansal S, Maharao N, Paine MF, Unadkat JD. Predicting the potential for cannabinoids to precipitate pharmacokinetic drug interactions via reversible inhibition or inactivation of major cytochromes p450. *Drug Metab Dispos.* 2020;48(10):1008-1017.
14. Rein JL. The nephrologist's guide to cannabis and cannabinoids. *Curr Opin Nephrol Hypertens.* 2020;29(2):248-257.
15. FDA. Center for Drug Evaluation and Research. Application Number: 206030Orig1s000. Clinical Pharmacology and Biopharmaceutics Review(s). Carbella (carbamazepine). https://www.accessdata.fda.gov/drugsatfda_docs/nda/2016/206030Orig1s000ClinPharmR.pdf. Date of Review June 25, 2014. Accessed January 9, 2026.
16. Bansal AD, Hill CE, Berns JS. Use of Antiepileptic Drugs in Patients with Chronic Kidney Disease and End Stage Renal Disease. *Semin Dial.* 2015;28(4):404-412.
17. Kandrotas RJ, Oles KS, Gal P, Love JM. Carbamazepine clearance in hemodialysis and hemoperfusion. *Dicp.* 1989;23(2):137-140.
18. Schuerer DJ, Brophy PD, Maxvold NJ, Kudelka T, Bunchman TE. High-efficiency dialysis for carbamazepine overdose. *J Toxicol Clin Toxicol.* 2000;38(3):321-323.
19. Tapolyai M, Campbell M, Dailey K, Udvari-Nagy S. Hemodialysis is as effective as hemoperfusion for drug removal in carbamazepine poisoning. *Nephron.* 2002;90(2):213-215.
20. Mahmoud SH. Antiepileptic Drug Removal by Continuous Renal Replacement Therapy: A Review of the Literature. *Clin Drug Investig.* 2017;37(1):7-23.
21. Narayan R, Rizzo M, Cole M. Successful treatment of severe carbamazepine toxicity with 5% albumin-enhanced continuous venovenous hemodialysis. *J Artif Organs.* 2014;17(2):206-209.
22. Smollin CG, Petrie MS, Kearney T. Carbamazepine and carbamazepine-10,11-epoxide clearance measurements during continuous venovenous hemofiltration in a massive overdose. *Clin Toxicol (Phila).* 2016;54(5):424-427.
23. Ravis W, Tolbert D, Karim A, Cloyd JC. Pharmacokinetics of Carbamazepine in Patients by Renal Function Status: IV Carbamazepine Formulation as a Short-Term Switch from Oral Carbamazepine. <https://aesnet.org/abstractslisting/pharmacokinetics-of-carbamazepine-in-patients-by-renal-function-status-iv-carbamazepine-formulation-as-a-short-term-switch-from-oral-carbamazepine>. Accessed Apr 8, 2026. AES; 3 December, 2016, 2016; Houston , Texas, USA.
24. Anderson GD, Hakimian S. Pharmacokinetic of antiepileptic drugs in patients with hepatic or renal impairment. *Clin Pharmacokinet.* 2014;53(1):29-49.
25. FDA. USA Food and Drug Administration. Tegretol (carbamazepine). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/018927Orig1s061;016608Orig1s122;020234Orig1s055lbl.pdf. Revised Sep 30, 2025. Accessed Jun 26, 2026.
26. FDA. USA Food and Drug Administration. Xcopri (cenobamate). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/212839s013lbl.pdf. Updated Aug 18, 2025. Accessed Jun 25, 2026.
27. EMA. European Medicines Agency. Summary of product characteristics. Ontozry (cenobamate). https://www.ema.europa.eu/en/documents/product-information/ontozry-epar-product-information_en.pdf. Updated Dec 3, 2025, Accessed Mar 18, 2026.
28. FDA. Center for Drug Evaluation and Research. Application Number: 212839Orig1s000. Clinical Pharmacology and Biopharmaceutics Review(s). Xcopri (cenobamate). https://www.accessdata.fda.gov/drugsatfda_docs/nda/2019/212839Orig1s000ClinPharmR.pdf Updated Nov 21, 2019. Accessed Mar 18, 2026.
29. FDA. USA Food and Drug Administration. Onfi (clobazam). https://www.accessdata.fda.gov/drugsatfda_docs/label/2024/202067s008,203993s010lbl.pdf. Revised Mar 12, 2024. Accessed May 8, 2026.
30. Roberts GW, Zoanetti GD. Clobazam and N-desmethyloclobazam serum concentrations in endstage renal failure and hemodialysis. *Ann Pharmacother.* 1994;28(7-8):966-967.
31. FDA. Center for Drug Evaluation and Research. Application Number: 202067Orig1s000. Clinical Pharmacology and Biopharmaceutics Review(s). Onfi (clobazam). https://www.accessdata.fda.gov/drugsatfda_docs/nda/2011/202067Orig1s000ClinPharmR.pdf. Updated Apr 11, 2011. Accessed May 12, 2026.
32. EMA. European Medicines Agency. Summary of product characteristics. Zebinix (eslicarbazepine acetate). https://www.ema.europa.eu/en/documents/product-information/baraclude-epar-product-information_en.pdf. Updated Mar 31, 2025. Accessed Nov 3, 2025.
33. FDA. USA Food and Drug Administration. Aptiom (eslicarbazepine acetate). https://www.accessdata.fda.gov/drugsatfda_docs/label/2019/022416s011lbl.pdf. Updated Mar 15, 2019. Accessed Jun 26, 2026.
34. Maia J, Almeida L, Falcão A, et al. Effect of renal impairment on the pharmacokinetics of eslicarbazepine acetate. *Int J Clin Pharmacol Ther.* 2008;46(3):119-130.
35. Mahmoud SH, Zhou XY, Ahmed SN. Managing the patient with epilepsy and renal impairment. *Seizure.* 2020;76:143-152.
36. Marquardt ED, Ishisaka DY, Batra KK, Chin B. Removal of ethosuximide and phenobarbital by peritoneal dialysis in a child. *Clin Pharm.* 1992;11(12):1030-1031.
37. EMA. European Medicines Agency. Summary of product characteristics. Afinitor (everolimus). <https://www.ema.europa.eu/en/medicines/human/EPAR/afinitor>. Updated Nov 20, 2025, Accessed Feb 6, 2026.
38. FDA. USA Food and Drug Administration. Felbatol (felbamate). https://www.accessdata.fda.gov/drugsatfda_docs/label/2012/020189s027lbl.pdf. Revised Aug 31, 2012. Accessed Feb 7, 2026.
39. Glue P, Sulowicz W, Colucci R, et al. Single-dose pharmacokinetics of felbamate in patients with renal dysfunction. *Br J Clin Pharmacol.* 1997;44(1):91-93.
40. FDA. USA Food and Drug Administration. Fintepla (fenfluramine). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/212102s017lbl.pdf. Updated Oct 15, 2025. Accessed Mar 27, 2026.

41. EMA. European Medicines Agency. Summary of product characteristics. Fintepla (fenfluramine). https://www.ema.europa.eu/en/documents/product-information/fintepla-epar-product-information_en.pdf. Updated Jan 9, 2026, Accessed Mar 27, 2026.
42. Blum RA, Comstock TJ, Sica DA, et al. Pharmacokinetics of gabapentin in subjects with various degrees of renal function. *Clin Pharmacol Ther.* 1994;56(2):154-159.
43. FDA. USA Food and Drug Administration. Neurontin (Gabapentin). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/020235s079,020882s060,021129s059lbl.pdf. Updated Apr 25, 2025. Accessed June 26, 2026.
44. Wong MO, Eldon MA, Keane WF, et al. Disposition of gabapentin in anuric subjects on hemodialysis. *J Clin Pharmacol.* 1995;35(6):622-626.
45. Ibrahim H, Oman Z, Schuelke M, Edwards JC. Treatment of Gabapentin Toxicity With Peritoneal Dialysis: Assessment of Gabapentin Clearance. *Am J Kidney Dis.* 2017;70(6):878-880.
46. FDA. USA Food and Drug Administration. Ztalmu (ganaxolone). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/215904s011s013lbl.pdf. Updated Oct 16, 2025. Accessed Jun 26, 2026.
47. EMA. European Medicines Agency. Summary of product characteristics. Ztalmu (ganaxolone): EPAR - Product Information. Updated Jan 15, 2026. Accessed Mar 18, 2026.
48. FDA. US Food and Drug Administration. Lacosamide (Vimpat). https://www.accessdata.fda.gov/drugsatfda_docs/label/2023/022253s057,022254s047,022255s039lbl.pdf. Revised Oct 16, 2023. Accessed Jun 26, 2026.
49. Cawello W, Fuhr U, Hering U, Maatouk H, Halabi A. Impact of impaired renal function on the pharmacokinetics of the antiepileptic drug lacosamide. *Clin Pharmacokinet.* 2013;52(10):897-906.
50. Bouajram RH, Awdishu L. A Clinician's Guide to Dosing Analgesics, Anticonvulsants, and Psychotropic Medications in Continuous Renal Replacement Therapy. *Kidney Int Rep.* 2021;6(8):2033-2048.
51. FDA. USA Food and Drug Administration. Lamictal (lamotrigine). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/020241s068s069,020764s061s062,022251s032s033lbl.pdf. Revised Oct 10, 2025. Accessed Mar 28, 2026.
52. Wootton R, Soul-Lawton J, Rolan PE, Sheung CT, Cooper JD, Posner J. Comparison of the pharmacokinetics of lamotrigine in patients with chronic renal failure and healthy volunteers. *Br J Clin Pharmacol.* 1997;43(1):23-27.
53. FDA. USA Food and Drug Administration. Keppra (levetiracetam). https://www.accessdata.fda.gov/drugsatfda_docs/label/2024/021035s115,021505s053lbl.pdf. Revised Dec 3, 2024. Accessed Jun 26, 2026.
54. Nakazawa Y, Shiraishi W, Matsuyoshi A, et al. Serum perampanel levels in patients with seizures are not affected by hemodialysis. *Epilepsia Open.* 2024;9(4):1597-1603.
55. FDA. Center for Drug Evaluation and Research. Application Number: 206030Orig1s000. Clinical Pharmacology and Biopharmaceutics Review(s). Keppra (levetiracetam). https://www.accessdata.fda.gov/drugsatfda_docs/nda/99/21035_Keppra_biopharmr_P1.pdf. Date of Review Nov 30, 1999. Accessed Mar 28, 2026.
56. Sweatman J, Al-Mahdi S, Lonsdale DO, Leaver S, Rhodes A. Levetiracetam dosing in continuous renal replacement therapy: A systematic review and development of a novel pharmacokinetic model to optimise dosing in critically ill patients. Do recommended doses achieve therapeutic drug concentrations? *J Intensive Care Soc.* 2025;26(2):193-204.
57. FDA. Product Information: Trileptal (oxcarbazepine). Film-coated tablets, for oral use. https://www.accessdata.fda.gov/drugsatfda_docs/label/2024/021014s050lbl.pdf. Revised Sep 23, 2025. Accessed Mar 29, 2026.
58. Schmidt D, Arroyo S, Baulac M, et al. Recommendations on the clinical use of oxcarbazepine in the treatment of epilepsy: a consensus view. *Acta Neurol Scand.* 2001;104(3):167-170.
59. FDA. Product Information: Oxtellar XR (oxcarbazepine). extended-release tablets, for oral use. https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/021014s049,021285s041lbl.pdf. Revised Sep 23, 2025. Accessed Jun 26, 2026.
60. Rouan MC, Lecaillon JB, Godbillon J, et al. The effect of renal impairment on the pharmacokinetics of oxcarbazepine and its metabolites. *Eur J Clin Pharmacol.* 1994;47(2):161-167.
61. EMA. European Medicines Agency. Summary of product characteristics. Fycompa (perampanel). https://www.ema.europa.eu/en/documents/product-information/fycompa-epar-product-information_en.pdf. Updated May 10, 2023. Accessed Apr 5, 2026.
62. FDA. Center for Drug Evaluation and Research. Fycompa (perampanel). Application Number: 202834. Clinical Pharmacology and Biopharmaceutics Review(s). Dec 2011. https://www.accessdata.fda.gov/drugsatfda_docs/nda/2012/202834Orig1s000ClinPharmR.pdf. Accessed May 8, 2026.
63. FDA. USA Food and Drug Administration. Fycompa (perampanel). https://www.accessdata.fda.gov/drugsatfda_docs/label/2024/202834Orig1s019lbl.pdf. Revised Dec 5, 2023. Accessed June 26, 2026.
64. Asconapé JJ. Use of antiepileptic drugs in hepatic and renal disease. *Handb Clin Neurol.* 2014;119:417-432.
65. Agarwal SK, Tiwari SC, Dash SC. Spectrum of poisoning requiring haemodialysis in a tertiary care hospital in India. *Int J Artif Organs.* 1993;16(1):20-22.
66. Palmer BF. Effectiveness of hemodialysis in the extracorporeal therapy of phenobarbital overdose. *Am J Kidney Dis.* 2000;36(3):640-643.
67. Zawada ET, Jr., Nappi J, Done G, Rollins D. Advances in the hemodialysis management of phenobarbital overdose. *South Med J.* 1983;76(1):6-8.

68. Ruhe M, Grautoff S, Kähler J, Pohle T. [Suicide attempt by means of phenobarbital overdose. Effective treatment with continuous veno-venous hemodialysis]. *Med Klin Intensivmed Notfmed*. 2016;111(2):141-144.
69. Lal R, Faiz S, Garg RK, Baweja KS, Guntupalli J, Finkel KW. Use of continuous venovenous hemodiafiltration in a case of severe phenobarbital poisoning. *Am J Kidney Dis*. 2006;48(2):e13-15.
70. Suzuki T, Suzuki T, Takatsuka H, Yamazaki S, Ishii I. Successful treatment of seizure disorder by evaluating phenobarbital clearance in a paediatric patient undergoing continuous haemodiafiltration. *J Clin Pharm Ther*. 2019;44(3):479-481.
71. Rosenberg S, Saraste L, Wide K. High phenobarbital clearance during continuous renal replacement therapy: a case report and pharmacokinetic analysis. *Medicine (Baltimore)*. 2014;93(7):e46.
72. Le Page AK, Stewart AE, Roehr CC, Johnstone LM, Graudins A. The Use of Peritoneal Dialysis in Phenobarbitone Toxicity in a Critically Unwell Neonate. *Neonatology*. 2018;113(2):117-121.
73. Porto I, John EG, Heiliczner J. Removal of phenobarbital during continuous cycling peritoneal dialysis in a child. *Pharmacotherapy*. 1997;17(4):832-835.
74. Israni RK, Kasbekar N, Haynes K, Berns JS. Use of antiepileptic drugs in patients with kidney disease. *Semin Dial*. 2006;19(5):408-416.
75. Whiting EG, Jr., Barrett O, Jr., Inmon TW. TREATMENT OF BARBITURATE POISONING. THE USE OF PERITONEAL DIALYSIS. *Calif Med*. 1965;102(5):367-369.
76. FDA. USA Food and Drug Administration. Dilantin (phenytoin sodium). https://www.accessdata.fda.gov/drugsatfda_docs/label/2022/084349s088lbl.pdf. Revised Sep 7, 2022. Accessed Jun 26, 2026.
77. FDA. USA Food and Drug Administration. Cerebyx (fosphenytoin). https://www.accessdata.fda.gov/drugsatfda_docs/label/2022/020450s046lbl.pdf. Revised Apr 28, 2022. Accessed Jun 26, 2026.
78. Lacerda G, Krummel T, Sabourdy C, Ryvlin P, Hirsch E. Optimizing therapy of seizures in patients with renal or hepatic dysfunction. *Neurology*. 2006;67(12 Suppl 4):S28-33.
79. Lau AH, Kronfol NO. Effect of continuous hemofiltration on phenytoin elimination. *Ther Drug Monit*. 1994;16(1):53-57.
80. Soriano VV, Tesoro EP, Kane SP. Characterization of Free Phenytoin Concentrations in End-Stage Renal Disease Using the Winter-Tozer Equation. *Ann Pharmacother*. 2017;51(8):669-674.
81. Aweeka FT, Gottwald MD, Gambertoglio JG, et al. Pharmacokinetics of fosphenytoin in patients with hepatic or renal disease. *Epilepsia*. 1999;40(6):777-782.
82. FDA. U.S. Food & Drug Administration. Drug Approvals and Databases. Lyrica (pregabalin). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/021446s046,022488s022lbl.pdf. Revised Apr 25, 2025. Accessed June 26, 2026.
83. Randinitis EJ, Posvar EL, Alvey CW, Sedman AJ, Cook JA, Bockbrader HN. Pharmacokinetics of pregabalin in subjects with various degrees of renal function. *J Clin Pharmacol*. 2003;43(3):277-283.
84. Rayner H, Baharani J, Smith S, Suresh V, Dasgupta I. Uraemic pruritus: relief of itching by gabapentin and pregabalin. *Nephron Clin Pract*. 2012;122(3-4):75-79.
85. Nielsen VT, Wijayasinghe N, Høgberg LCG, Bøgevig S. Case report: A comatose patient with pregabalin overdose successfully treated with continuous renal replacement therapy. *Front Med (Lausanne)*. 2023;10:1125653.
86. Lenkathula N, Cascella M. Primidone. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK562297/>. Updated Feb 28, 2024. Accessed: Apr 5, 2026.
87. Streeter JM, Berry DJ, Jones JA, Groggin MJ. Clearance of phenylethylmalonamide during haemodialysis of a patient with renal failure. *Ther Drug Monit*. 1990;12(3):281-283.
88. Martinez C, Gatti G, Sasso E, Calzetti S, Perucca E. The disposition of primidone in elderly patients. *Br J Clin Pharmacol*. 1990;30(4):607-611.
89. Stern EL. Possible phenylethylmalondiamide (PEMA) intoxication. *Ann Neurol*. 1977;2(4):356-357.
90. Heipertz R, Guthoff A, Bernhardt W. Primidone metabolism in renal insufficiency and acute intoxication. *J Neurol*. 1979;221(2):101-104.
91. Humayun MJ, Wadhwa R. Rufinamide. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK557595/>. Updated Apr 17, 2023. Accessed Apr 2, 2026.
92. FDA. USA Food and Drug Administration. Banzel (rufinamide). https://www.accessdata.fda.gov/drugsatfda_docs/label/2019/021911s017,201367s008lbl.pdf. Updated Nov 28, 2019. Accessed Feb 7, 2026.
93. Perucca E, Cloyd J, Critchley D, Fuseau E. Rufinamide: clinical pharmacokinetics and concentration-response relationships in patients with epilepsy. *Epilepsia*. 2008;49(7):1123-1141.
94. EMA. European Medicines Agency. Summary of product characteristics. Diacomit (Stiripentol). https://www.ema.europa.eu/en/documents/product-information/diacomit-epar-product-information_en.pdf. Updated Oct 20, 2025. Accessed Apr 2, 2026.
95. FDA. USA Food and Drug Administration. Diacomit (stiripentol). https://www.accessdata.fda.gov/drugsatfda_docs/label/2018/206709s000,207223s000lbl.pdf. Updated Jul 14, 2022. Accessed Nov Apr 1, 2026.
96. Cato A, 3rd, Gustavson LE, Qian J, El-Shourbagy T, Kelly EA. Effect of renal impairment on the pharmacokinetics and tolerability of tiagabine. *Epilepsia*. 1998;39(1):43-47.
97. FDA. USA Food and Drug Administration. Gabitril (tiagabine). https://www.accessdata.fda.gov/drugsatfda_docs/label/2025/210365s023lbl.pdf. Updated Aug 9, 2016. Accessed Apr 1, 2026.

98. NIH. PubChem. PUG REST. <https://pubchem.ncbi.nlm.nih.gov/docs/pug-rest#section=Compound-Property-Tables>. Accessed Apr 2, 2026.
99. FDA. USA Food and Drug Administration. Topamax (topiramate). https://www.accessdata.fda.gov/drugsatfda_docs/label/2026/020505s068lbl.pdf. Revised Mar 6, 2026. Accessed Jun 26, 2026.
100. Manitpisitkul P, Curtin CR, Shalayda K, Wang SS, Ford L, Heald DL. Pharmacokinetics of topiramate in patients with renal impairment, end-stage renal disease undergoing hemodialysis, or hepatic impairment. *Epilepsy Res.* 2014;108(5):891-901.
101. Browning L, Parker D, Jr., Liu-DeRyke X, Shah A, Coplin WM, Rhoney DH. Possible removal of topiramate by continuous renal replacement therapy. *J Neurol Sci.* 2010;288(1-2):186-189.
102. FDA. USA Food and Drug Administration. Depakote (divalproex sodium). https://www.accessdata.fda.gov/drugsatfda_docs/label/2026/018723s073lbl.pdf. Revised Mar 31, 2026. Accessed Jun 26, 2026.
103. Orr JM, Farrell K, Abbott FS, Ferguson S, Godolphin WJ. The effects of peritoneal dialysis on the single dose and steady state pharmacokinetics of valproic acid in a uremic epileptic child. *Eur J Clin Pharmacol.* 1983;24(3):387-390.
104. Khan F, Menon U, Sagastume R, Ramsay R. Clearance of valproic acid by continuous renal replacement therapy in a patient with status epilepticus. <https://aesnet.org/abstractslisting/clearance-of-valproic-acid-by-continuous-renal-replacement-therapy-in-a-patient-with-status-epilepticus>. AES; Dec 5, 2013, 2013; Washington, D.C.
105. FDA. USA Food and Drug Administration. Sabril (vigabatrin). https://www.accessdata.fda.gov/drugsatfda_docs/label/2021/020427s025,022006s026lbl.pdf. Revised Oct 20, 2021. Accessed Jun 26, 2026.
106. Bachmann D, Ritz R, Wad N, Haefeli WE. Vigabatrin dosing during haemodialysis. *Seizure.* 1996;5(3):239-242.
107. FDA. USA Food and Drug Administration. Zonergan (zonisamide). https://www.accessdata.fda.gov/drugsatfda_docs/label/2020/020789s036lbl.pdf. Updated Apr 13, 2020. Accessed Apr 3, 2026.
108. Ijiri Y, Inoue T, Fukuda F, et al. Dialyzability of the antiepileptic drug zonisamide in patients undergoing hemodialysis. *Epilepsia.* 2004;45(8):924-927.
109. FDA. USA Food and Drug Administration. Zonergan (Zonisamide). https://www.accessdata.fda.gov/drugsatfda_docs/label/2020/020789s036lbl.pdf. Revised Apr 13, 2020. Accessed Jun 26, 2026.
110. Dhaliwal JS, Rosani A, Saadabadi A. Diazepam. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK537022/>. Updated Aug 28, 2023. Accessed Mar 19, 2026.
111. Balogh A, Fünfstück R, Demme U, et al. Dialysability of benzodiazepines by haemodialysis and controlled sequential ultrafiltration (CSU) in vitro. *Acta Pharmacol Toxicol (Copenh).* 1981;49(3):174-180.
112. Ochs HR, Greenblatt DJ, Kaschell HJ, Klehr U, Divoll M, Abernethy DR. Diazepam kinetics in patients with renal insufficiency or hyperthyroidism. *Br J Clin Pharmacol.* 1981;12(6):829-832.
113. FDA. USA Food and Drug Administration. Ativan (lorazepam). https://www.accessdata.fda.gov/drugsatfda_docs/label/2023/017794s049lbl.pdf. Updated Jan 13, 2023. Accessed Jun 26, 2026.
114. Swart EL, de Jongh J, Zuideveld KP, Danhof M, Thijs LG, Strack van Schijndel RJ. Population pharmacokinetics of lorazepam and midazolam and their metabolites in intensive care patients on continuous venovenous hemofiltration. *Am J Kidney Dis.* 2005;45(2):360-371.
115. EMA. European Medicines Agency. Summary of product characteristics. Buccolam (Midazolam). https://www.ema.europa.eu/en/documents/product-information/buccolam-epar-product-information_en.pdf. Updated Nov 13, 2024. Accessed Mar 27, 2026.
116. Bauer TM, Ritz R, Haberthür C, et al. Prolonged sedation due to accumulation of conjugated metabolites of midazolam. *Lancet.* 1995;346(8968):145-147.
117. FDA. USA Food and Drug Administration. Nayzilam (midazolam). https://www.accessdata.fda.gov/drugsatfda_docs/label/2023/211321s008lbl.pdf. Revised Jan 13, 2023. Accessed Mar 27, 2026.
118. Thomson BK, Nolin TD, Velenosi TJ, et al. Effect of CKD and dialysis modality on exposure to drugs cleared by nonrenal mechanisms. *Am J Kidney Dis.* 2015;65(4):574-582.
119. Tatosian DA, Yee KL, Zhang Z, et al. A Microdose Cocktail to Evaluate Drug Interactions in Patients with Renal Impairment. *Clin Pharmacol Ther.* 2021;109(2):403-415.
120. Kong W, Pan Y, Wu Y, et al. Microdose Cocktail Study Reveals the Activity and Key Influencing Factors of OATP1B, P-Gp, BCRP, and CYP3A in End-Stage Renal Disease Patients. *Clin Pharmacol Ther.* 2025;117(5):1303-1312.