

CYP3A4 DDI Qualification

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<https://github.com/Open-Systems-Pharmacology/OSP-Qualification-Reports>

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1 Introduction

1.1 Objective

This **qualification report** evaluates for the PBPK platform **PK-Sim** (as part of the open systems pharmacology (OSP) suite) the ability to perform simulations with the intended purpose to predict cytochrome P450 3A4 (**CYP3A4**)-mediated drug-drug interactions (**DDI**).

To demonstrate the level of confidence, the predictive performance of the platform for this indented purpose is assessed via a network of PBPK models of selected index CYP3A4 DDI perpetrators (covering the range from strong induction to strong inhibition), and respective sensitive index CYP3A4 victim drugs and a comprehensive dataset from published clinical DDI studies. All PBPK models represent whole-body PBPK models, which allow dynamic DDI simulations in organs expressing CYP3A4.

The respective *qualification plan* to produce this *qualification report* is transparently provided open-source (<https://github.com/Open-Systems-Pharmacology/Qualification-DDI-CYP3A4>). The same applies for all presented PBPK models including *evaluation reports* on model building and evaluation of each model (<https://github.com/Open-Systems-Pharmacology/OSP-PBPK-Model-Library>).

Evaluation reports including descriptions on model building and detailed evaluations of the included models are documented separately (see [Section 1.2](#)).

Please refer to the [Appendix](#) to learn more details:

- An overview over the Open Systems Pharmacology Suite is given in chapter [Section 5.1](#)
- [Section 5.2](#) shows the implementation of the underlying mathematical equations for drug-drug interactions in the OSP suite.
- A detailed general description of the performed qualification workflow (*qualification plan*, *qualification report*, etc.) can be found in chapter [Section 5.3](#).

1.2 CYP3A4 DDI Network

To qualify the OSP suite for the prediction of the CYP3A4 DDI potential of new drugs, a set of verified PBPK models of index perpetrators, covering the range from strong CYP3A4 induction to strong inhibition, and respective CYP3A4 DDI victim drugs is specified to set up a CYP3A4-mediated DDI modeling network.

The following perpetrator compounds were selected:

- **Rifampicin** (strong CYP3A4 inducer)
Model snapshot and evaluation plan (*release v1.2*): <https://github.com/Open-Systems-Pharmacology/Rifampicin-Model/releases/tag/v1.2>
- **Carbamazepine** (moderate CYP3A4 inducer)
Model snapshot and evaluation plan (*release v1.3*): <https://github.com/Open-Systems-Pharmacology/Carbamazepine-Model/releases/tag/v1.3>

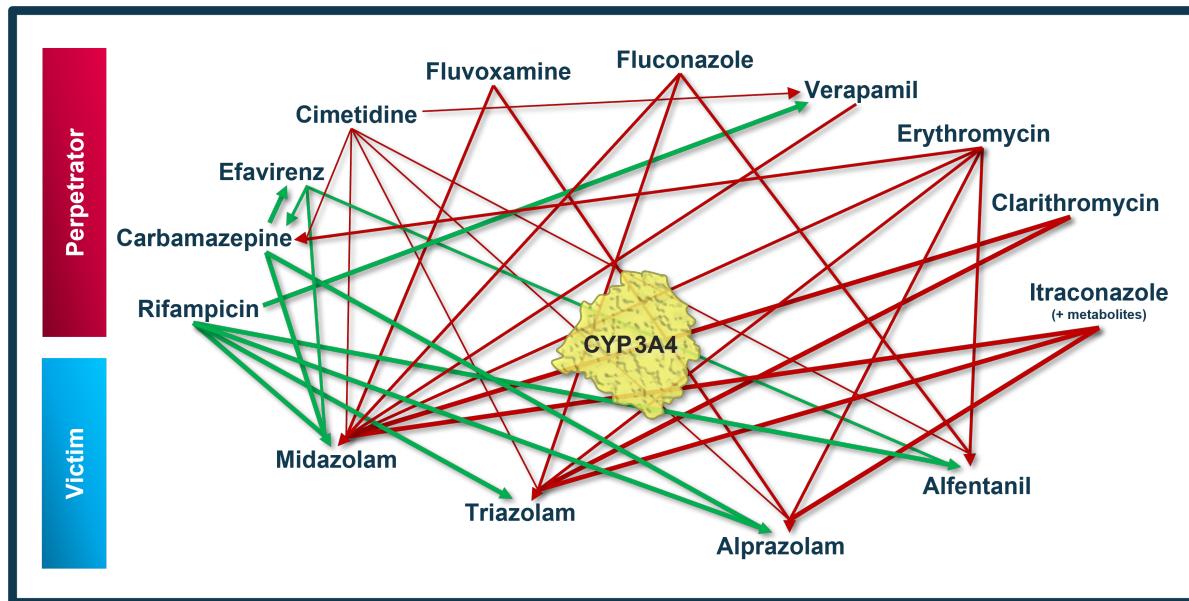
- **Efavirenz** (moderate CYP3A4 inducer)
Model snapshot and evaluation plan (*release v1.1*): <https://github.com/Open-Systems-Pharmacology/Efavirenz-Model/releases/tag/v1.1>
- **Cimetidine** (weak CYP3A4 inhibitor)
Model snapshot and evaluation plan (*release v1.2*): <https://github.com/Open-Systems-Pharmacology/Cimetidine-Model/releases/tag/v1.2>
- **Fluvoxamine** (weak/moderate CYP3A4 inhibitor)
Model snapshot and evaluation plan (*release v1.2*): <https://github.com/Open-Systems-Pharmacology/Fluvoxamine-Model/releases/tag/v1.2>
- **Verapamil** (moderate CYP3A4 inhibitor)
Model snapshot and evaluation plan (*release v1.2*): <https://github.com/Open-Systems-Pharmacology/Verapamil-Model/releases/tag/v1.2>
- **Fluconazole** (moderate CYP3A4 inhibitor)
Model snapshot and evaluation plan (*release v1.0*): <https://github.com/Open-Systems-Pharmacology/Fluconazole-Model/releases/tag/v1.0>
- **Erythromycin** (moderate CYP3A4 inhibitor)
Model snapshot and evaluation plan (*release v1.3*): <https://github.com/Open-Systems-Pharmacology/Erythromycin-Model/releases/tag/v1.3>
- **Clarithromycin** (strong CYP3A4 inhibitor)
Model snapshot and evaluation plan (*release v1.2*): <https://github.com/Open-Systems-Pharmacology/Clarithromycin-Model/releases/tag/v1.2>
- **Itraconazole** including metabolites (strong CYP3A4 inhibitor)
Model snapshot and evaluation plan (*release v1.3*): <https://github.com/Open-Systems-Pharmacology/Itraconazole-Model/releases/tag/v1.3>

The following sensitive CYP3A4 substrates as victim drugs were selected:

- **Midazolam**
Model snapshot and evaluation plan (*release v1.1*): <https://github.com/Open-Systems-Pharmacology/Midazolam-Model/releases/tag/v1.1>
- **Triazolam**
Model snapshot and evaluation plan (*release v1.1*): <https://github.com/Open-Systems-Pharmacology/Triazolam-Model/releases/tag/v1.1>
- **Alprazolam**
Model snapshot and evaluation plan (*release v1.1*): <https://github.com/Open-Systems-Pharmacology/Alprazolam-Model/releases/tag/v1.1>
- **Alfentanil**
Model snapshot and evaluation plan (*release v2.2*): <https://github.com/Open-Systems-Pharmacology/Alfentanil-Model/releases/tag/v2.2>

Figure 1 shows the prespecified and developed DDI modeling network of interacting perpetrator and victim drugs for the OSP suite qualification of predicting CYP3A4-mediated DDI.

Figure 1: CYP3A4 DDI modeling network



The arrows indicate where at least one clinical DDI study between the two connected substances was available and included in the model network. Red indicates inhibition and green indicates induction as the primary type of interaction. Thin arrows indicate weak, mid-thick arrows moderate and thick arrows strong CYP3A4 modulation by the perpetrator.

The published DDI studies between the respective perpetrators and victim drugs were simulated and compared to observed data. The following sections give an overview of the clinical studies being part of this qualification report. The respective data identifier (DataID) refers to the ID of the dataset in the OSP PK database, version 1.5 (<https://github.com/Open-Systems-Pharmacology/Database-for-observed-data/releases/tag/v1.5>).

Carbamazepine - Alprazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Carbamazepine-Alprazolam-DDI/releases/tag/v1.1>

The carbamazepine-alprazolam interaction was evaluated using one clinical DDI study ([Furukori 1998](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
1457	CYP3A4	Carbamazepine / alprazolam	Carbamazepine: 100 mg po TID for 10 days Alprazolam: 0.8 mg po single dose, 2 hours after the 22 nd carbamazepine dose	Furukori 1998

Carbamazepine - Efavirenz DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Carbamazepine-Efavirenz-DDI/releases/tag/v1.1>

The carbamazepine-efavirenz interaction was evaluated using one clinical DDI study ([Ji 2008](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
959	CYP3A4	Carbamazepine / efavirenz	Study Arm 1: Carbamazepine (starting with the 15 th dose of efavirenz): 200 mg po QD for 3 days, followed by 200 mg po BID for 3 days, followed by 400 mg po QD for 16 days Efavirenz: 600 mg po QD for 35 days	Ji 2008

Carbamazepine - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Carbamazepine-Midazolam-DDI/releases/tag/v1.0>

The carbamazepine-midazolam interaction was evaluated using three clinical DDI studies ([Lutz 2018](#), [Kanefendt 2023](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
1460	CYP3A4	Carbamazepine / midazolam	Carbamazepine: 100 mg po BID for 2 days, followed by 200 mg po BID for 2 days, followed by 300 mg po BID for 22 days Midazolam: 2 mg po single dose, concomitantly with the 49 th carbamazepine dose	Lutz 2018
943	CYP3A4	Carbamazepine / midazolam	Carbamazepine: 100 mg po BID for 2 days, followed by 200 mg po BID for 2 days, followed by 300 mg po for 17 days Midazolam: 1 mg po single dose, 10 hours after the 26 th carbamazepine dose	Kanefendt 2023
1133	CYP3A4	Carbamazepine / midazolam	Carbamazepine: 100 mg po BID for 2 days, followed by 200 mg po BID for 2 days, followed by 300 mg po for 18 days Midazolam: 1 mg po single dose, 12 hours after the 28 th carbamazepine dose	Kanefendt 2023

Cimetidine - Alfentanil DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Cimetidine-Alfentanil-DDI/releases/tag/v1.2>.

The cimetidine-alfentanil interaction was evaluated using a single clinical DDI study quantifying the interaction following two different dosing regimens ([Kienlen 1993](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1344	CYP3A4	Cimetidine / alfentanil	Cimetidine: 1200 mg iv OD over 3 days Alfentanil: 125 µg/kg iv on day 3 concomitantly with the cimetidine dose	No cross-over study! Parallel group design -> the two groups may not really be comparable given the low number of subjects and considering alfentanil PK variability	Kienlen 1993

Cimetidine - Alprazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Cimetidine-Alprazolam-DDI/releases/tag/v1.2>.

The cimetidine-alprazolam interaction was evaluated using two clinical DDI studies quantifying the interaction following two different dosing regimens ([Pourbaix 1985](#), [Abernethy 1983](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1340	CYP3A4	Cimetidine / alprazolam	Cimetidine: 200 mg po TID and 400 mg at bedtime over two weeks Alprazolam: 0.5 mg po OD in the second week concomitantly with morning dose		Pourbaix 1985
1332	CYP3A4	Cimetidine / alprazolam	Cimetidine: 300 mg po QID (4 times) Alprazolam: 1 mg po single dose concomitantly with cimetidine dose at 12 h		Abernethy 1983

Cimetidine - Carbamazepine DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Cimetidine-Carbamazepine-DDI/releases/tag/v1.1>

The cimetidine-carbamazepine interaction was evaluated using one clinical DDI study ([Dalton 1985](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
900	CYP3A4	Cimetidine / carbamazepine	Cimetidine: 300 mg po QID for 9 days Carbamazepine: 600 mg po single dose, one hour before the 9 th dose of cimetidine		Dalton 1985

Cimetidine - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Cimetidine-Midazolam-DDI/releases/tag/v1.2>

The cimetidine-midazolam interaction was evaluated using five clinical DDI studies quantifying the interaction following six different dosing regimens ([Elliott 1984](#), [Fee 1987](#), [Greenblatt 1986](#), [Martinez 1999](#), [Salonen 1986](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1346	CYP3A4	Cimetidine / midazolam	Cimetidine: 200 mg po TID and 400 mg nocte on day before study and 200 mg on study day Midazolam: 7.5 mg po single dose, 2.5 hours after last cimetidine dose		Elliott 1984
1324	CYP3A4	Cimetidine / midazolam	Cimetidine: 400 mg po BID (3 times) Midazolam: 15 mg po single dose, 1 hour after the last cimetidine dose		Fee 1987
1319	CYP3A4	Cimetidine / midazolam	Cimetidine: 300 mg po QID (8 times) Midazolam: 5 mg iv single dose, concomitantly with the 5 th cimetidine dose		Greenblatt 1986
1321	CYP3A4	Cimetidine / midazolam	Cimetidine: 300 mg po QID (8 times) Midazolam: 15 mg po single dose concomitantly with the 5 th cimetidine dose		Greenblatt 1986
1322	CYP3A4	Cimetidine / midazolam	Cimetidine: 800 mg po single dose Midazolam: 7.5 mg po single dose concomitantly with cimetidine dose		Martinez 1999
1326	CYP3A4	Cimetidine / midazolam	Cimetidine: 400 mg po single dose Midazolam: 15 mg po single dose 2 hours after cimetidine dose		Salonen 1986

Cimetidine - Triazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Cimetidine-Triazolam-DDI/releases/tag/v1.2>.

The cimetidine-triazolam interaction was evaluated using four clinical DDI studies quantifying the interaction following four different dosing regimens ([Pourbaix 1985](#), [Abernethy 1983](#), [Cox 1986](#), [Friedman 1988](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1342	CYP3A4	Cimetidine / triazolam	Cimetidine: 200 mg po TID and 400 mg at bedtime over two weeks Triazolam: 0.5 mg po OD in the second week concomitantly with bedtime dose		Pourbaix 1985
1334	CYP3A4	Cimetidine / triazolam	Cimetidine: 300 mg po QID (4 times) Triazolam: 0.5 mg po single dose concomitantly with cimetidine dose at 12 h		Abernethy 1983
1338	CYP3A4	Cimetidine / triazolam	Cimetidine: 300 mg po QID (4 times) Triazolam: 0.5 mg intraduodenal single dose, 13 hours after study start		Cox 1986
1336	CYP3A4	Cimetidine / triazolam	Cimetidine: 300 mg po QID (8 times) Triazolam: 0.5 mg po single dose concomitantly with the 5 th cimetidine dose		Friedman 1988

Cimetidine - Verapamil DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Cimetidine-Verapamil-DDI/releases/tag/v1.2>.

The cimetidine-verapamil interaction was evaluated using a single clinical DDI study quantifying the interaction following two different dosing regimens ([Smith 1984](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1328	CYP3A4	Cimetidine / verapamil	Cimetidine: 300 mg po QID over eight days Verapamil: 10 mg iv on day 8 concomitantly with the morning dose		Smith 1984
1330	CYP3A4	Cimetidine / verapamil	Cimetidine: 300 mg po QID over eight days Verapamil: 120 mg po on day 8 concomitantly with the morning dose		Smith 1984

Clarithromycin - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Clarithromycin-Midazolam-DDI/releases/tag/v1.2>

The clarithromycin-midazolam interaction was evaluated using eight clinical DDI studies quantifying the interaction following ten different dosing regimens ([Gorski 1998](#), [Gurley 2006](#), [Gurley 2008a](#), [Markert 2013](#), [Prueksaritanont 2017](#), [Quinney 2008](#), [van Dyk 2018](#), [Yeates 1997](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
175	CYP3A4	Clarithromycin / midazolam	Clarithromycin: 500 mg po BID for 7 days Midazolam: 0.05 mg/kg iv single dose, 2 hours after the 13 th clarithromycin dose		Gorski 1998
173	CYP3A4	Clarithromycin / midazolam	Clarithromycin: 500 mg po BID for 7 days Midazolam: 4 mg po single dose, 2 hours after the 13 th clarithromycin dose		Gorski 1998
217	CYP3A4	Clarithromycin / midazolam	Clarithromycin: 500 mg po BID for 7 days Midazolam: 8 mg po single dose, 2 hours after the 13 th clarithromycin dose		Gurley 2006
223	CYP3A4	Clarithromycin / midazolam	Clarithromycin: 500 mg po BID for 7 days Midazolam: 8 mg po single dose, 2 hours after the 13 th clarithromycin dose		Gurley 2008a
354	CYP3A4	Clarithromycin / midazolam	Clarithromycin: 500 mg po BID for 4 days Midazolam: 3 mg po single dose, 0.25 hours after the 7 th clarithromycin dose		Markert 2013
1099	CYP3A4	Clarithromycin / midazolam	Clarithromycin: 500 mg po BID for 5 days Midazolam: 0.01 mg po single dose, administered simultaneously with the 7 th clarithromycin dose		Pruksaritanont 2017
2027	CYP3A4	Clarithromycin / midazolam	Clarithromycin: 500 mg po BID for 7 days Midazolam: 0.05 mg/kg iv single dose, 2 hours after the 13 th clarithromycin dose		Quinney 2008
2030	CYP3A4	Clarithromycin / midazolam	Clarithromycin: 500 mg po BID for 7 days Midazolam: 3.5 mg po single dose, 2 hours after the 13 th clarithromycin dose		Quinney 2008
2004	CYP3A4	Clarithromycin / midazolam	Rifampicin: 300 mg po QD for 7 days Wash-out phase for 3 days Clarithromycin: 250 mg po BID for 3 days Midazolam: 1 mg po single dose, 12 hours after the last rifampicin dose and again 12 hours after the last clarithromycin dose	Only assessment in Caucasian subjects simulated. AUC_{0-6h} ratio reported and simulated for comparison.	van Dyk 2018
469	CYP3A4	Clarithromycin / midazolam	Clarithromycin: 250 mg po BID for 5 days Midazolam: 15 mg po single dose, 1.5 hours after the 9 th clarithromycin dose		Yeates 1997

Clarithromycin - Triazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Clarithromycin-Triazolam-DDI/releases/tag/v1.2>

The clarithromycin-triazolam interaction was evaluated using one clinical DDI study ([Greenblatt 1998a](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
1102	CYP3A4	Clarithromycin / triazolam	Clarithromycin: 500 mg po twice daily at irregular time intervals for 2 days Triazolam: 0.125 mg po single dose, 1 hour after the 3 rd clarithromycin dose	Greenblatt 1998a

Efavirenz - Alfentanil-DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Efavirenz-Alfentanil-DDI/releases/tag/v1.1>

The efavirenz-alfentanil interaction was evaluated using one clinical DDI study that includes iv and oral administration of alfentanil ([Kharasch 2012](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
801	CYP3A4	Efavirenz / alfentanil	Efavirenz: 600 mg po OD for 20 days Alfentanil: 43 µg/kg po single dose, 1/2 hour after the 15 th efavirenz dose		Kharasch 2012
803	CYP3A4	Efavirenz / alfentanil	Efavirenz: 600 mg po OD for 20 days Alfentanil: 15 µg/kg iv single dose, 1/2 hour after the 16 th efavirenz dose		Kharasch 2012

Efavirenz - Carbamazepine DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Efavirenz-Carbamazepine-DDI/releases/tag/v1.0>

The efavirenz-carbamazepine interaction was evaluated using one clinical DDI study ([Ji 2008](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
961	CYP3A4	Efavirenz / carbamazepine	Study Arm 2: Efavirenz (starting with the 25 th dose of carbamazepine): 600 mg po QD for 14 days Carbamazepine: 200 mg po QD for 3 days, followed by 200 mg po BID for 3 days, followed by 400 mg po QD for 30 days	Ji 2008

Efavirenz - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Efavirenz-Midazolam-DDI/releases/tag/v1.2>

The efavirenz-midazolam interaction was evaluated using two clinical DDI studies, one using single dose and one using one multiple dose administration of efavirenz ([Katzenmaier 2010](#), [Mikus 2017](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
2041	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po OD over 14 days Midazolam: 3 mg po single dose on day 14 together with efavirenz dose		Katzenmaier 2010
2044	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 4 mg po single dose, 12 hours (day 1) after efavirenz dose		Mikus 2017
2045	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 2 mg iv single dose, 18 hours (day 1) after efavirenz dose		Mikus 2017
2047	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 4 mg po single dose, 132 hours (day 6) after efavirenz dose		Mikus 2017
2048	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 2 mg iv single dose, 138 hours (day 6) after efavirenz dose		Mikus 2017
2049	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 4 mg po single dose, 252 hours (day 11) after efavirenz dose		Mikus 2017
2050	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 2 mg iv single dose, 258 hours (day 11) after efavirenz dose		Mikus 2017
2051	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 4 mg po single dose, 372 hours (day 16) after efavirenz dose		Mikus 2017
2052	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 2 mg iv single dose, 378 hours (day 16) after efavirenz dose		Mikus 2017
2053	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 4 mg po single dose, 516 hours (*day 22) after efavirenz dose		Mikus 2017
2054	CYP3A4	Efavirenz / midazolam	Efavirenz: 400 mg po SD on day 1 Midazolam: 2 mg iv single dose, 522 hours (day 22) after efavirenz dose		Mikus 2017

Erythromycin - Alfentanil DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Erythromycin-Alfentanil-DDI/releases/tag/v1.2>

The erythromycin-alfentanil interaction was evaluated using one clinical DDI study ([Bartkowski 1989](#)) quantifying the interaction following two different dosing regimens. Additionally, the plasma concentration-time profile of an individual investigated in this study was subsequently reported in a later study ([Bartkowski 1993](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
779	CYP3A4	Erythromycin / alfentanil	Erythromycin: 500 mg po single dose (enteric coated tablet containing erythromycin as free base) Alfentanil: 0.05 mg/kg iv single dose, 1.5 hours after erythromycin dose	Bartkowski 1989
780	CYP3A4	Erythromycin / alfentanil	Erythromycin: 500 mg po BID for 7 days (enteric coated tablet containing erythromycin as free base) Alfentanil: 0.05 mg/kg iv single dose, 1.5 hours after the 13 th erythromycin dose	Bartkowski 1989

Erythromycin - Alprazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Erythromycin-Alprazolam-DDI/releases/tag/v1.2>

The erythromycin-alprazolam interaction was evaluated using one clinical DDI study ([Yasui 1996](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
777	CYP3A4	Erythromycin / alprazolam	Erythromycin: 400 mg po TID for 10 days (filmcoated tablet containing erythromycin stearate) Alprazolam: 0.8 mg po single dose, 2 hours after the 22 nd erythromycin dose	Yasui 1996

Erythromycin - Carbamazepine DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Erythromycin-Carbamazepine-DDI/releases/tag/v1.1>

The erythromycin-carbamazepine interaction was evaluated using three clinical DDI studies ([Barzaghi 1987](#), [Miles 1989](#), [Wong 1983](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
465	CYP3A4	Erythromycin / carbamazepine	Erythromycin: 500 mg po TID for 10 days Carbamazepine: 400 mg po single dose, administered on the 7 th day of treatment with erythromycin	Barzaghi 1987
1157	CYP3A4	Erythromycin / carbamazepine	Erythromycin: 250 mg po QID for 3 days, starting on day 15 of carbamazepine administration Carbamazepine: 300 mg po QD for 17 days	Miles 1989
1158	CYP3A4	Erythromycin / carbamazepine	Erythromycin: 250 mg po QID for 3 days, starting on day 15 of carbamazepine administration Carbamazepine: 400 mg po QD for 17 days	Miles 1989
1154	CYP3A4	Erythromycin / carbamazepine	Erythromycin: 250 mg po QID for 8 days Carbamazepine: 400 mg po single dose, administered on the 6 th day of treatment with erythromycin	Wong 1983

Erythromycin - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Erythromycin-Midazolam-DDI/releases/tag/v1.2>

The erythromycin-midazolam interaction was evaluated using five clinical DDI studies quantifying the interaction following nine different dosing regimens ([Carls 2014](#), [Okudaira 2007](#), [Olkkola 1993](#), [Swart 2002](#), [Zimmermann 1996](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
828	CYP3A4	Erythromycin / midazolam	Erythromycin: 250 mg po single dose (filmcoated tablet containing erythromycin stearate) Midazolam: 0.03 mg po single dose, 1 hour after erythromycin dose	AUC _{2-4h} ratio reported and simulated for comparison.	Carls 2014
829	CYP3A4	Erythromycin / midazolam	Erythromycin: 1000 mg single dose (filmcoated tablet containing erythromycin stearate) Midazolam: 0.03 mg po single dose, 1 hour after erythromycin dose	AUC _{2-4h} ratio reported and simulated for comparison.	Carls 2014
362	CYP3A4	Erythromycin / midazolam	Erythromycin: 200 mg po four times daily for 7 days (filmcoated tablet containing erythromycin stearate) Midazolam: 2.5 mg po single dose, 1 hour after the 5 th erythromycin dose	Subjects received 5 mg midazolam po in control phase	Okudaira 2007
363	CYP3A4	Erythromycin / midazolam	Erythromycin: 200 mg po four times daily for 7 days (filmcoated tablet containing erythromycin stearate) Midazolam: 2.5 mg po single dose, 1 hour after the 13 th erythromycin dose	Subjects received 5 mg midazolam po in control phase	Okudaira 2007
364	CYP3A4	Erythromycin / midazolam	Erythromycin: 200 mg po four times daily for 7 days (filmcoated tablet containing erythromycin stearate) Midazolam: 2.5 mg po single dose, 1 hour after the 25 th erythromycin dose	Subjects received 5 mg midazolam po in control phase	Okudaira 2007
368	CYP3A4	Erythromycin / midazolam	Erythromycin: 500 mg po TID for 6 days (enteric coated tablet containing erythromycin as free base) Midazolam: 0.05 mg/kg iv single dose, 2 hours after the 17 th erythromycin dose		Olkkola 1993
366	CYP3A4	Erythromycin / midazolam	Erythromycin: 500 mg po TID for 6 days (enteric coated tablet containing erythromycin as free base) Midazolam: 15 mg po single dose, 2 hours after the 17 th erythromycin dose		Olkkola 1993

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
420	CYP3A4	Erythromycin / midazolam	Erythromycin: 500 mg po QID for 5 days (filmcoated tablet containing erythromycin stearate) Midazolam: 0.075 mg/kg mg iv single dose, together with the 96 th erythromycin dose		Swart 2002
471	CYP3A4	Erythromycin / midazolam	Erythromycin: 500 mg po TID for 5 days (filmcoated tablet containing erythromycin stearate) Midazolam: 0.8 mg po single dose, 1.5 hours after the 13 th erythromycin dose		Zimmermann 1996

Erythromycin - Triazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Erythromycin-Triazolam-DDI/releases/tag/v1.2>

The erythromycin-triazolam interaction was evaluated using two clinical DDI studies ([Greenblatt 1998](#), [Phillips 1986](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
781	CYP3A4	Erythromycin / triazolam	Erythromycin: 500 mg po twice daily for 2 days Triazolam: 0.125 mg po single dose, 1 hour after the 3 rd erythromycin dose	Greenblatt 1998
757	CYP3A4	Erythromycin / triazolam	Erythromycin: 333 mg po TID for 3 days Triazolam: 0.5 mg po single dose, together with the last erythromycin dose	Phillips 1986

Fluconazole - Alfentanil DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Fluconazole-Alfentanil-DDI/releases/tag/v1.0>.

The fluconazole-alfentanil interaction was evaluated using a single clinical DDI study quantifying the interaction following two different dosing regimens ([Palkama 1998](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1398	CYP3A4	Fluconazole / alfentanil	Fluconazole: 400 mg iv infusion for 60 min single administration Alfentanil: 0.02 mg/kg iv infusion, 1 hour after start of fluconazole dosing		Palkama 1998
1399	CYP3A4	Fluconazole / alfentanil	Fluconazole: 400 mg po single administration Alfentanil: 0.02 mg/kg iv infusion, 1 hour after the fluconazole dose		Palkama 1998

Fluconazole - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Fluconazole-Midazolam-DDI/releases/tag/v1.0>.

The fluconazole-midazolam interaction was evaluated using two clinical DDI studies quantifying the interaction following 5 different dosing regimens ([Ahonen 1997](#), [Olkkola 1996](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1392	CYP3A4	Fluconazole / midazolam	Fluconazole: 400 mg iv infusion for 60 min Midazolam: 7.5 mg po single dose, 1 hour after start of fluconazole dosing		Ahonen 1997
1393	CYP3A4	Fluconazole / midazolam	Fluconazole: 400 mg po Midazolam: 7.5 mg po single dose, 1 hour after the fluconazole dose		Ahonen 1997
380	CYP3A4	Fluconazole / midazolam	Fluconazole: 400 mg po QD (day 1) then 200 mg QD for 5 days Midazolam: 7.5 mg po, 2 hours after the day 1 fluconazole dose		Olkkola 1996
381	CYP3A4	Fluconazole / midazolam	Fluconazole: 400 mg po QD (day 1) then 200 mg QD for 5 days Midazolam: 0.05 mg/kg iv infusion, 2 hours after the day 4 fluconazole dose		Olkkola 1996
381	CYP3A4	Fluconazole / midazolam	Fluconazole: 400 mg po QD (day 1) then 200 mg QD for 5 days Midazolam: 7.5 mg po, 2 hours after the day 6 fluconazole dose		Olkkola 1996

Fluconazole - Triazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Fluconazole-Triazolam-DDI/releases/tag/v1.0>.

The fluconazole-triazolam interaction was evaluated using a single clinical DDI study quantifying the interaction following three different dosing regimens ([Varhe 1996](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1394	CYP3A4	Fluconazole / triazolam	Fluconazole: 50 mg po QD for 4 days Triazolam: 0.25 mg po single dose, 1 hour after last fluconazole dose		Varhe 1996
1395	CYP3A4	Fluconazole / triazolam	Fluconazole: 100 mg po QD for 4 days Triazolam: 0.25 mg po single dose, 1 hour after last fluconazole dose		Varhe 1996
1396	CYP3A4	Fluconazole / triazolam	Fluconazole: 200 mg po QD for 4 days Triazolam: 0.25 mg po single dose, 1 hour after last fluconazole dose		Varhe 1996

Fluvoxamine - Alprazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Fluvoxamine-Alprazolam-DDI/releases/tag/v1.1>

The fluvoxamine-alprazolam interaction was evaluated using one clinical DDI study quantifying the interaction following the first dose and in steady-state ([Fleishaker 1994](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Clinical study
1104	CYP3A4	Fluvoxamine / alprazolam	Fluvoxamine: 50 mg fluvoxamine maleate QD for 3 days, followed by 100 mg fluvoxamine maleate QD for 7 days Alprazolam: 1 mg po four times daily on Day 7 starting together with the 7 th fluvoxamine dose	Fleishaker 1994
1113	CYP3A4	Fluvoxamine / alprazolam	Fluvoxamine: 50 mg fluvoxamine maleate QD for 3 days, followed by 100 mg fluvoxamine maleate QD for 7 days Alprazolam: 1 mg po four times daily on Days 7 - 10 starting together with the 7 th fluvoxamine dose	Fleishaker 1994

Fluvoxamine - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Fluvoxamine-Midazolam-DDI/releases/tag/v1.2>

The fluvoxamine / midazolam interaction was evaluated using two clinical DDI studies ([Kashuba 1998](#), [Lam 2003](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
2007	CYP3A4	Fluvoxamine / midazolam	Fluvoxamine: titrated to a daily dose of 150 mg (50 mg in the morning (6 a.m.), 50 mg in the evening (8 p.m.)) Midazolam: 0.025 mg/kg iv single dose, 3 hours after a morning fluvoxamine dose	Observed data: Baseline (control) assessment: mean of six measures (every 2 weeks) Phenotyping (fluvoxamine treatment) assessment: mean of two measures (14 days and 28 days after the start of fluvoxamine treatment), midazolam administered at 9 a.m. Simulated: the midazolam dose was administered 3 weeks after the start of fluvoxamine as an approximation of the two observed assessments	Kashuba 1998
1089	CYP3A4	Fluvoxamine / midazolam	Fluvoxamine: titrated to a daily dose of 200 mg (100 mg BID) Midazolam: 10 mg po single dose, 1 hour after a fluvoxamine steady state dose		Lam 2003

Itraconazole - Alprazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Itraconazole-Alprazolam-DDI/releases/tag/v1.2>

The itraconazole / alprazolam interaction was evaluated using one clinical DDI study ([Yasui 1998](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1026	CYP3A4	Itraconazole / alprazolam	Itraconazole: 200 mg po once daily (6 doses, capsule fasted) Alprazolam: 0.8 mg po single dose, 1 hour after 4th itraconazole dose		Yasui 1998

Itraconazole - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Itraconazole-Midazolam-DDI/releases/tag/v1.2>

The itraconazole / midazolam interaction was evaluated using seven clinical DDI studies including 12 different clinical settings ([Ahonen 1995](#), [Backman 1998](#), [Olkola 1994](#), [Olkola 1996](#), [Pruksaritanont 2017](#), [Templeton 2010](#), [Yu 2004](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
50	CYP3A4	Itraconazole / midazolam	Itraconazole: 100 mg po once daily (4 doses, capsule fasted) Midazolam: 7.5 mg po single dose, simultaneous with 4th itraconazole dose		Ahonen 1995
58	CYP3A4	Itraconazole / midazolam	Itraconazole: 200 mg po once daily (4 doses, capsule fasted) Midazolam: 7.5 mg po single dose, 2 hours after 4th itraconazole dose	Midazolam simulated as 15 mg for comparability to control phase, in which a 15 mg dose was given.	Backman 1998
59	CYP3A4	Itraconazole / midazolam	Itraconazole: 200 mg po once daily (4 doses, capsule fasted) Midazolam: 7.5 mg po single dose, 4 days after 4th itraconazole dose	Midazolam simulated as 15 mg for comparability to control phase, in which a 15 mg dose was given.	Backman 1998
370	CYP3A4	Itraconazole / midazolam	Itraconazole: 200 mg po once daily (4 doses, capsule fasted) Midazolam: 7.5 mg po single dose, 1 hours after 4th itraconazole dose		Olkola 1994
377	CYP3A4	Itraconazole / midazolam	Itraconazole: 200 mg po once daily (6 doses, capsule fasted) Midazolam: 7.5 mg po single dose, 2 hours after 1st itraconazole dose		Olkola 1996
378	CYP3A4	Itraconazole / midazolam	Itraconazole: 200 mg po once daily (6 doses, capsule fasted) Midazolam: 0.05 mg/kg iv single dose, 2 hours after 4th itraconazole dose		Olkola 1996
379	CYP3A4	Itraconazole / midazolam	Itraconazole: 200 mg po once daily (6 doses, capsule fasted) Midazolam: 7.5 mg po single dose, 2 hours after 6th itraconazole dose		Olkola 1996
1097	CYP3A4	Itraconazole / midazolam	Itraconazole: 200 mg po once daily (5 doses) (solution fasted) Midazolam: 10 µg po single dose, simultaneous with 4th itraconazole dose		Prueksaritanont 2017

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
424	CYP3A4	Itraconazole / midazolam	Itraconazole: 50 mg po single dose (solution fasted) Midazolam: 2 mg po single dose, 4 hours after itraconazole dose		Templeton 2010
425	CYP3A4	Itraconazole / midazolam	Itraconazole: 100 mg po single dose (solution fasted) Midazolam: 2 mg po single dose , 4 hours after itraconazole dose		Templeton 2010
426	CYP3A4	Itraconazole / midazolam	Itraconazole: 400 mg po single dose (solution fasted) Midazolam: 2 mg po single dose, 4 hours after itraconazole dose		Templeton 2010
199	CYP3A4	Itraconazole / midazolam	Itraconazole: 200 mg po once daily (4 doses, capsule fasted) Midazolam: 1 mg iv single dose, simultaneous with ^{4th} itraconazole dose	Only assessment in CYP3A5*3/*3 genotype subjects simulated.	Yu 2004

Itraconazole - Triazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Itraconazole-Triazolam-DDI/releases/tag/v1.2>

The itraconazole / triazolam interaction was evaluated using two clinical DDI studies including 5 different clinical settings ([Neuvonen 1996](#), [Varhe 1994](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1078	CYP3A4	Itraconazole / triazolam	Itraconazole: 200 mg po single dose (capsule fasted) triazolam: 0.25 mg po single dose, simultaneous with itraconazole dose	3 hours fasting before triazolam/itraconazole administration	Neuvonen 1996
1079	CYP3A4	Itraconazole / triazolam	Itraconazole: 200 mg po single dose (capsule fed) triazolam: 0.25 mg po single dose, 3 hours after itraconazole dose	itraconazole dose was taken after lunch	Neuvonen 1996
1080	CYP3A4	Itraconazole / triazolam	Itraconazole: 200 mg po single dose (capsule fed) triazolam: 0.25 mg po single dose, 12 hours after itraconazole dose	itraconazole dose was taken with a snack, 3 hours fasting before triazolam administration	Neuvonen 1996
1081	CYP3A4	Itraconazole / triazolam	Itraconazole: 200 mg po single dose (capsule fed) triazolam: 0.25 mg po single dose, 24 hours after itraconazole dose	itraconazole dose was taken with a snack, 3 hours fasting before triazolam administration	Neuvonen 1996
1029	CYP3A4	Itraconazole / triazolam	Itraconazole: 200 mg po once daily (4 doses, capsule fasted) triazolam: 0.25 mg po single dose, 1 hour after 4th itraconazole dose		Varhe 1994

Rifampicin - Alfentanil DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Rifampicin-Alfentanil-DDI/releases/tag/v1.2>

The rifampicin / alfentanil interaction was evaluated using 5 clinical DDI studies including 16 different clinical settings ([Kharasch 1997](#), [Kharasch 2004](#), [Kharasch 2011](#), [Kharasch 2011b](#), [Phimmasone 2001](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
278	CYP3A4	Rifampicin / alfentanil	Rifampicin: 600 mg po once daily (5 doses) Alfentanil: 20 µg/kg IV single dose, 24.5 h after 5th rifampicin dose		Kharasch 1997
283	CYP3A4	Rifampicin / alfentanil	Rifampicin: 600 mg po once daily (6 doses) Alfentanil: 15 µg/kg IV single dose, 9 h after 5th rifampicin dose		Kharasch 2004
288	CYP3A4	Rifampicin / alfentanil	Rifampicin: 600 mg po once daily (6 doses) Alfentanil: 60 µg/kg PO single dose, 9 h after 6th rifampicin dose		Kharasch 2004
299	CYP3A4	Rifampicin / alfentanil	Rifampicin: 5 mg po once daily (6 doses) Alfentanil: 15 µg/kg IV single dose, 13 h after 5th rifampicin dose		Kharasch 2011
300	CYP3A4	Rifampicin / alfentanil	Rifampicin: 10 mg po once daily (6 doses) Alfentanil: 15 µg/kg IV single dose, 13 h after 5th rifampicin dose		Kharasch 2011
301	CYP3A4	Rifampicin / alfentanil	Rifampicin: 25 mg po once daily (6 doses) Alfentanil: 15 µg/kg IV single dose, 13 h after 5th rifampicin dose		Kharasch 2011
302	CYP3A4	Rifampicin / alfentanil	Rifampicin: 75 mg po once daily (6 doses) Alfentanil: 15 µg/kg IV single dose, 13 h after 5th rifampicin dose		Kharasch 2011
309	CYP3A4	Rifampicin / alfentanil	Rifampicin: 5 mg po once daily (6 doses) Alfentanil: 75 µg/kg PO single dose, 13 h after 6th rifampicin dose		Kharasch 2011
310	CYP3A4	Rifampicin / alfentanil	Rifampicin: 10 mg po once daily (6 doses) Alfentanil: 75 µg/kg PO single dose, 13 h after 6th rifampicin dose		Kharasch 2011

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
311	CYP3A4	Rifampicin / alfentanil	Rifampicin: 25 mg po once daily (6 doses) Alfentanil: 75 µg/kg PO single dose, 13 h after 6th rifampicin dose		Kharasch 2011
312	CYP3A4	Rifampicin / alfentanil	Rifampicin: 75 mg po once daily (6 doses) Alfentanil: 75 µg/kg PO single dose, 13 h after 6th rifampicin dose		Kharasch 2011
763	CYP3A4	Rifampicin / alfentanil	Rifampicin: 600 mg po once daily (6 doses) Alfentanil: 1 mg IV single dose, 12 h after 5th rifampicin dose	sequential administration of intravenous unlabeled alfentanil and oral deuterated alfentanil	Kharasch 2011b
771	CYP3A4	Rifampicin / alfentanil	Rifampicin: 600 mg po once daily (6 doses) Alfentanil: 4 mg PO single dose, 15 h after 5th rifampicin dose	sequential administration of intravenous unlabeled alfentanil and oral deuterated alfentanil	Kharasch 2011b
767	CYP3A4	Rifampicin / alfentanil	Rifampicin: 600 mg po once daily (6 doses) Alfentanil: 1 mg IV single dose, 12 h after 6th rifampicin dose	simultaneous administration of intravenous unlabeled alfentanil and oral deuterated alfentanil	Kharasch 2011b
775	CYP3A4	Rifampicin / alfentanil	Rifampicin: 600 mg po once daily (6 doses) Alfentanil: 4 mg PO single dose, 12 h after 6th rifampicin dose	simultaneous administration of intravenous unlabeled alfentanil and oral deuterated alfentanil	Kharasch 2011b
391	CYP3A4	Rifampicin / alfentanil	Rifampicin: 600 mg po once daily (5 doses) Alfentanil: 15 µg/kg IV single dose, 11 h after 5th rifampicin dose		Phimmasone 2001

Rifampicin - Alprazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Rifampicin-Alprazolam-DDI/releases/tag/v1.2>

The rifampicin-alprazolam interaction was evaluated using two clinical DDI studies quantifying the interaction in three clinical settings ([Gashaw 2003](#), [Schmider 1999](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comments	Clinical study
2009	CYP3A4	Rifampicin / alprazolam	Rifampicin: 450 mg, five doses at irregular times intervals over 4 days Alprazolam: 1 mg po single dose, 14 hours after the last rifampicin dose		Gashaw 2003
2010	CYP3A4	Rifampicin / alprazolam	Rifampicin: 450 mg, five doses at irregular times intervals over 4 days followed by a wash-out phase for 14 days Alprazolam: 1 mg po single dose after the wash-out phase (i.e. 350 hours after the last rifampicin dose)		Gashaw 2003
1001	CYP3A4	Rifampicin / alprazolam	Rifampicin: 450 mg po QD for 4 days Alprazolam: 1 mg po single dose, 24 hours after the last rifampicin dose	Administration time of alprazolam relative to rifampin not reported; it was assumed that alprazolam was administered 24h after the last rifampin dose	Schmider 1999

Rifampicin - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Rifampicin-Midazolam-DDI/releases/tag/v1.2>

The rifampicin / midazolam interaction was evaluated using 24 clinical DDI studies including 43 different clinical settings ([Backman 1996](#), [Backman 1998](#), [Björkhem-Bergman 2013](#), [Chattopadhyay 2018](#), [Chung 2006](#), [Eap 2004](#), [Gorski 2003](#), [Gurley 2006](#), [Gurley 2008a](#), [Kharasch 1997](#), [Kharasch 2004](#), [Kharasch 2011](#), [Kim 2018](#), [Link 2008](#), [Lutz 2018](#), [Phimmasone 2001](#), [Pruksaritanont 2017](#), [Reitman 2011](#), [Shin 2013](#), [Shin 2016](#), [Szalat 2007](#), [van Dyk 2018](#), [Wiesinger 2011](#), [Yu 2004](#)).

In the study by [Eap 2004](#), the induction of CYP3A4 by rifampicin was evaluated using first 0.075 mg and one day later 7.5 and orally administered midazolam. The magnitude of the DDI with the low dose was much lower than for the higher dose (AUC ratio 0.44 vs. 0.09), which can actually only be explained by issues with the limit of detection after induction for the small midazolam dose considering the entire set of observed data. Therefore, as well as in [Almond 2016](#), the dataset of the low dose setting was excluded from this analysis.

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
54	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (5 doses) Midazolam: 15 mg PO single dose, 17 h after 5th rifampicin dose		Backman 1996
56	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (5 doses) Midazolam: 15 mg PO single dose, 17 h after 5th rifampicin dose (Phase IV)		Backman 1998
57	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (5 doses) Midazolam: 15 mg PO single dose, 7 days after 5th rifampicin dose (Phase V)		Backman 1998
1355	CYP3A4	Rifampicin / midazolam	Rifampicin: 10 mg po once daily (14 doses) Midazolam: 4 mg PO single dose, 1 day after 14th rifampicin dose		Björkhem-Bergman 2013
1356	CYP3A4	Rifampicin / midazolam	Rifampicin: 20 mg po once daily (14 doses) Midazolam: 4 mg PO single dose, 1 day after 14th rifampicin dose		Björkhem-Bergman 2013
1357	CYP3A4	Rifampicin / midazolam	Rifampicin: 100 mg po once daily (14 doses) Midazolam: 4 mg PO single dose, 1 day after 14th rifampicin dose		Björkhem-Bergman 2013
1362	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily morning administrations (11 doses), 8th dose of rifampicin was taken in the evening (12 h after intake of midazolam) Midazolam: 1 mg PO single dose on day 8 (24 hours after the 7th rifampicin dose)	Subjects received a single dose of vilaprisan 4 mg simultaneously with midazolam (in both phases).	Chattopadhyay 2018
113	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (9 doses) Midazolam: 0.075 mg/kg PO single dose, 22 h after 7th rifampicin dose		Chung 2006
129	CYP3A4	Rifampicin / midazolam	Rifampicin: 450 mg po once daily (5 doses) Midazolam: 0.075 mg PO single dose, 18 h after 4th rifampicin dose	Dataset excluded (see comment above)	Eap 2004
132	CYP3A4	Rifampicin / midazolam	Rifampicin: 450 mg po once daily (5 doses) Midazolam: 7.5 mg PO single dose, 18 h after 5th rifampicin dose		Eap 2004

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
179	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (7 doses) Midazolam: 0.05 mg/kg IV single dose, 12 h after 6th rifampicin dose		Gorski 2003
177	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (7 doses) Midazolam: 6 mg PO single dose, 12 h after 6th rifampicin dose	Subjects received a 4 mg midazolam dose in control phase.	Gorski 2003
215	CYP3A4	Rifampicin / midazolam	Rifampicin: 300 mg po twice daily (14 doses, 7 days) Midazolam: 8 mg PO single dose, 2 h after 13th rifampicin dose		Gurley 2006
221	CYP3A4	Rifampicin / midazolam	Rifampicin: 300 mg po twice daily (14 doses, 7 days) Midazolam: 8 mg PO single dose, 2 h after 13th rifampicin dose		Gurley 2008a
276	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (5 doses) Midazolam: 1 mg IV single dose, 24 h after 5th rifampicin dose		Kharasch 1997
280	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (6 doses) Midazolam: 1 mg IV single dose, 8 h after 5th rifampicin dose		Kharasch 2004
286	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (6 doses) Midazolam: 3 mg PO single dose, 8 h after 6th rifampicin dose		Kharasch 2004
294	CYP3A4	Rifampicin / midazolam	Rifampicin: 5 mg po once daily (6 doses) Midazolam: 1 mg IV single dose, 12 h after 5th rifampicin dose		Kharasch 2011
295	CYP3A4	Rifampicin / midazolam	Rifampicin: 10 mg po once daily (6 doses) Midazolam: 1 mg IV single dose, 12 h after 5th rifampicin dose		Kharasch 2011
296	CYP3A4	Rifampicin / midazolam	Rifampicin: 25 mg po once daily (6 doses) Midazolam: 1 mg IV single dose, 12 h after 5th rifampicin dose		Kharasch 2011
297	CYP3A4	Rifampicin / midazolam	Rifampicin: 75 mg po once daily (6 doses) Midazolam: 1 mg IV single dose, 12 h after 5th rifampicin dose		Kharasch 2011

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
304	CYP3A4	Rifampicin / midazolam	Rifampicin: 5 mg po once daily (6 doses) Midazolam: 3 mg PO single dose, 12 h after 6th rifampicin dose		Kharasch 2011
305	CYP3A4	Rifampicin / midazolam	Rifampicin: 10 mg po once daily (6 doses) Midazolam: 3 mg PO single dose, 12 h after 6th rifampicin dose		Kharasch 2011
306	CYP3A4	Rifampicin / midazolam	Rifampicin: 25 mg po once daily (6 doses) Midazolam: 3 mg PO single dose, 12 h after 6th rifampicin dose		Kharasch 2011
307	CYP3A4	Rifampicin / midazolam	Rifampicin: 75 mg po once daily (6 doses) Midazolam: 3 mg PO single dose, 12 h after 6th rifampicin dose		Kharasch 2011
2036	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (10 doses) Midazolam: 2.5 mg IV single dose, simultaneous with 10th rifampicin dose	Only assessment in male subjects simulated. Subjects received a 1 mg midazolam dose in control phase. Observed reported dose-normalized AUCR back-calculated to non dose-normalized AUCR.	Kim 2018
342	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (6 doses) Midazolam: 2 mg IV single dose, 24 h after 6th rifampicin dose		Link 2008
344	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (6 doses) Midazolam: 7.5 mg PO single dose, 24 h after 6th rifampicin dose		Link 2008
1350	CYP3A4	Rifampicin / midazolam	Rifampicin: 2 mg po once daily (18 doses) Midazolam: 2 mg PO single dose, 12 h after 10th rifampicin dose	Cohort2, Cocktail study	Lutz 2008
1351	CYP3A4	Rifampicin / midazolam	Rifampicin: 10 mg po once daily (18 doses) Midazolam: 2 mg PO single dose, 12 h after 10th rifampicin dose	Cohort 1, Cocktail study	Lutz 2008
1352	CYP3A4	Rifampicin / midazolam	Rifampicin: 10 mg po once daily (18 doses), then 75 mg po once daily (18 doses) Midazolam: 2 mg PO single dose, 12 h after 10th 75 mg rifampicin dose	Cohort 1, Cocktail study	Lutz 2008

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1353	CYP3A4	Rifampicin / midazolam	Rifampicin: 2 mg po once daily (18 doses), then 600 mg po once daily (18 doses) Midazolam: 2 mg PO single dose, 12 h after 10th 600mg rifampicin dose	Cohort 2, Cocktail study	Lutz 2008
389	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (5 doses) Midazolam: 1 mg IV single dose, 10 h after 5th rifampicin dose		Phimmasone 2001
1098	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po SD Midazolam: 10 µg PO single dose, simultaneous with rifampicin dose		Prueksaritanont 2017
392	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (4 weeks) Midazolam: 2 mg PO single dose, simultaneous with 28th rifampicin dose	PK data of midazolam administered 28 days after the last rifampicin dose served as <i>control</i> (reference)	Reitman 2011
393	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (4 weeks) Midazolam: 2 mg PO single dose, 7 days after 28th rifampicin dose	PK data of midazolam administered 28 days after the last rifampicin dose served as <i>control</i> (reference)	Reitman 2011
394	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (4 weeks) Midazolam: 2 mg PO single dose, 14 days after 28th rifampicin dose	PK data of midazolam administered 28 days after the last rifampicin dose served as <i>control</i> (reference)	Reitman 2011
1092	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (10 doses) Midazolam: 2.5 mg IV single dose, simultaneous h with 10th rifampicin dose	Subjects received a 1 mg midazolam dose in control phase. Observed reported dose-normalized AUCR back-calculated to non dose-normalized AUCR.	Shin 2013
1095	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (10 doses) Midazolam: 2.5 mg IV single dose, simultaneous h with 10th rifampicin dose	Subjects received a 1 mg midazolam dose in control phase. Observed reported dose-normalized AUCR back-calculated to non dose-normalized AUCR.	Shin 2016
422	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (7 doses) Midazolam: 0.05 mg/kg IV single dose, 12 h after 12th rifampicin dose		Szalat 2007
2002	CYP3A4	Rifampicin / midazolam	Rifampicin: 300 mg po once daily (7 doses) Midazolam: 1 mg PO single dose, 12 h after 7th rifampicin dose	Only assessment in Caucasian subjects simulated. AUC_{0-6h} ratio reported and simulated for comparison.	van Dyk 2018

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
204	CYP3A4	Rifampicin / midazolam	Rifampicin: 10 mg po once daily (11 doses) Midazolam: 1 mg PO single dose, 12 h after 8th rifampicin dose	In the study midazolam was coadministered with either etonogestrel, dienogest, drospirenone, levonorgestrel or norethindrone.	Wiesinger 2020
205	CYP3A4	Rifampicin / midazolam	Rifampicin: 11 doses of 10 mg po once daily, followed by 11 doses of 600 mg po once daily Midazolam: 1 mg PO single dose, 12 h after 8th 600 mg rifampicin dose (after the 19 th overall rifampicin dose)	In the study midazolam was coadministered with either etonogestrel, dienogest, drospirenone, levonorgestrel or norethindrone.	Wiesinger 2020
202	CYP3A4	Rifampicin / midazolam	Rifampicin: 600 mg po once daily (10 doses) Midazolam: 2 mg IV single dose, 24 h after 10th rifampicin dose	Only assessment in CYP3A5*3/*3 genotype subjects simulated. Subjects received a 1 mg midazolam dose in control phase. Observed reported dose-normalized AUCR back-calculated to non dose-normalized AUCR.	Yu 2004

Rifampicin - Triazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Rifampicin-Triazolam-DDI/releases/tag/v1.2>

The rifampicin-triazolam interaction was evaluated using one clinical DDI study ([Villikka 1997](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comments	Clinical study
1004	CYP3A4	Rifampicin / triazolam	Rifampicin: 600 mg QD for 5 days Triazolam: 0.5 mg po single dose, 17 hours after the last rifampicin dose		Villikka 1997

Rifampicin - Verapamil DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Rifampicin-Verapamil-DDI/releases/tag/v1.1>

The rifampicin / verapamil interaction was evaluated using 1 clinical DDI study including 2 different clinical settings ([Barbarash 1988](#)).

DataID	Enzyme, Transporter	Perpetrator / victim	Study design	Comments	Clinical study
2056	CYP3A4 (and CYP2C8)	Rifampicin / verapamil	Rifampicin: 600 mg QD for 15 days Verapamil: 10 mg iv single dose, 12 hours after the 13 th rifampicin dose		Barbarash 1988
2058	CYP3A4 (and CYP2C8), P-gp*	Rifampicin / verapamil	Rifampicin: 600 mg QD for 15 days Verapamil: 120 mg po single dose, 12 hours after the 15 th rifampicin dose		Barbarash 1988

* The substrate characteristics of verapamil towards P-gp are not considered in the verapamil PBPK model applied in this qualification (<https://github.com/Open-Systems-Pharmacology/Verapamil-Model/releases/tag/v1.0>).

Verapamil - Midazolam DDI

The release of the snapshot containing the respective simulations can be found here:

<https://github.com/Open-Systems-Pharmacology/Verapamil-Midazolam-DDI/releases/tag/v1.3>

The verapamil / midazolam interaction was evaluated using two clinical DDI studies including 3 different clinical settings ([Backman 1994](#), [Wang 2005](#)).

DataID	Enzyme	Perpetrator / victim	Study design	Comment	Clinical study
1108	CYP3A4	Verapamil / midazolam	Verapamil: 80 mg po three times a day (5 doses) Midazolam: 15 mg po single dose, 1 hours after 4th verapamil dose		Backman 1994
1111	CYP3A4	Verapamil / midazolam	Verapamil: 240 mg po once daily (7 doses, sustained release) Midazolam: 0.05 mg/kg iv single dose, 24 hours after the 7th verapamil dose		Wang 2005
1116	CYP3A4	Verapamil / midazolam	Verapamil: 240 mg po once daily (7 doses, sustained release) Midazolam: 4 mg/kg po single dose, 48 hours after the 7th verapamil dose		Wang 2005

2 Qualification of Use Case CYP3A4-mediated DDI

The following section shows the correlations between observed and model-predicted AUC and C_{max} ratios, respectively.

Specifically, the PBPK model performance for the PK parameters **AUC ratio (AUCR)** and **C_{max} ratio (CMAXR)** is assessed via:

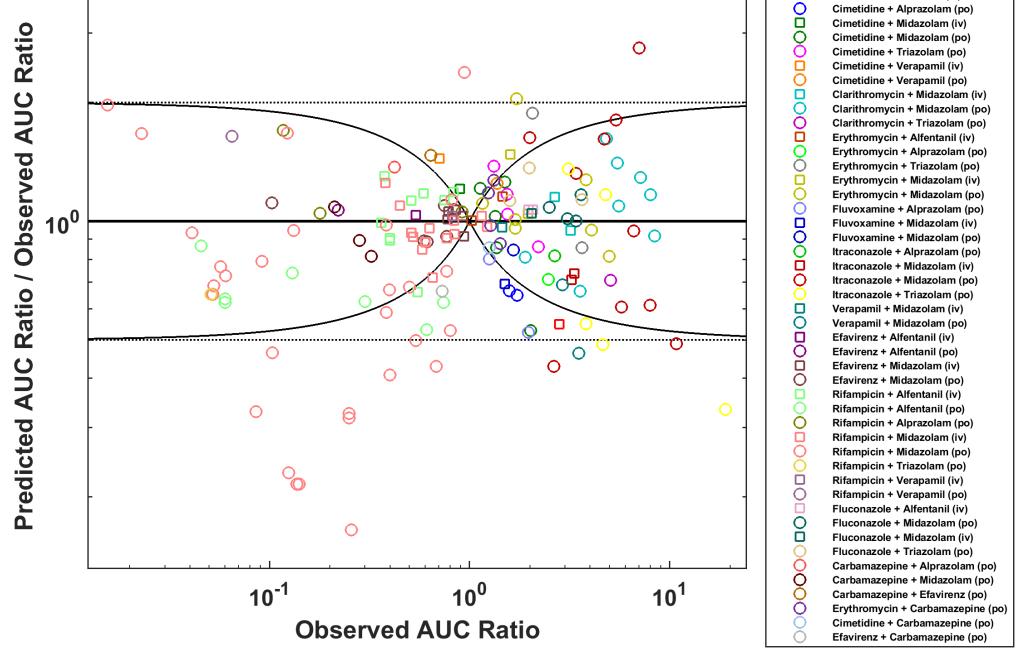
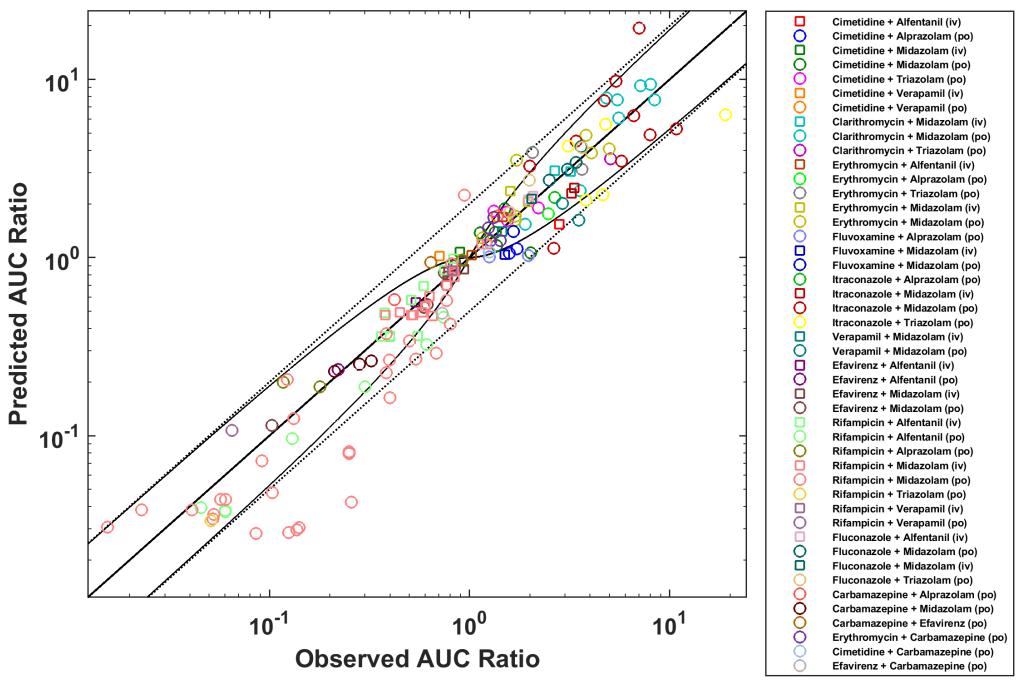
- predicted (*Pred*) vs. observed (*Obs*) plots
- $Pred/Obs$ vs. *Obs* plots
- geometric mean fold error (GMFE):

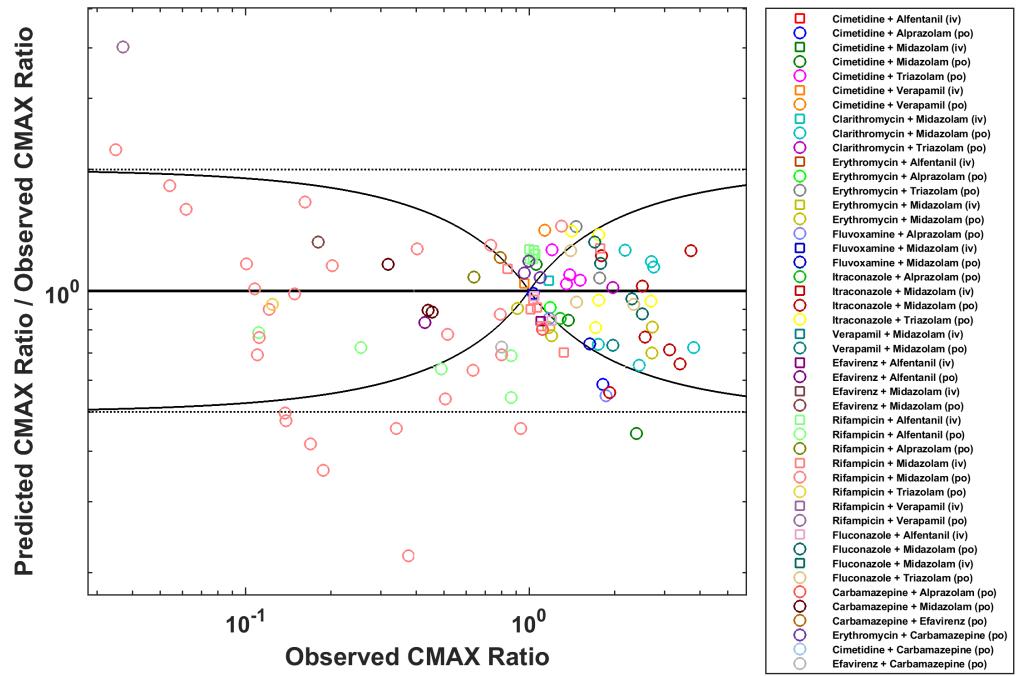
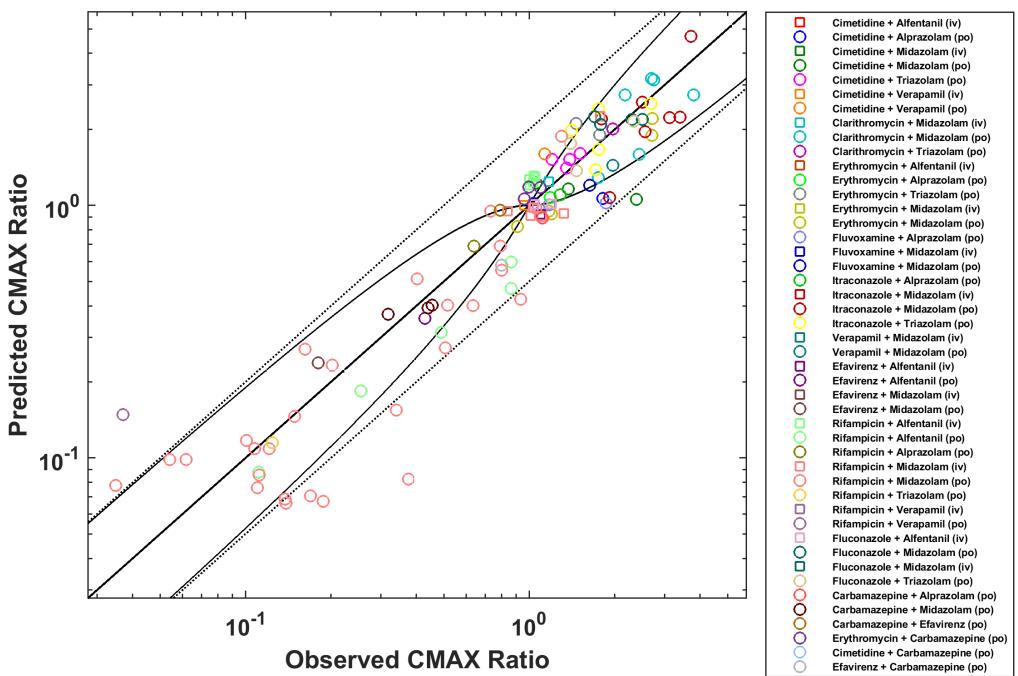
$$10^{\frac{\sum |\log(\frac{Pred}{Obs})|}{n}}$$

- number of AUCR and CMAXR falling within 2-fold error range and within the limits as suggested by [Guest et al. 2011](#)
- detailed table of results for each study

In the plots,

- the dotted lines denote 0.50–2.00 (2-fold) criterion,
- the solid lines denote the limits as suggested by [Guest et al. 2011](#),
- the bold solid line denotes the unity line,
- each color represents one combination of drugs,
- squares represent studies with intravenous administration of the victim drug and circles represent studies with oral administration of the victim drug.





GMFE (AUC) = 1.379540

GMFE (CMAX) = 1.334018

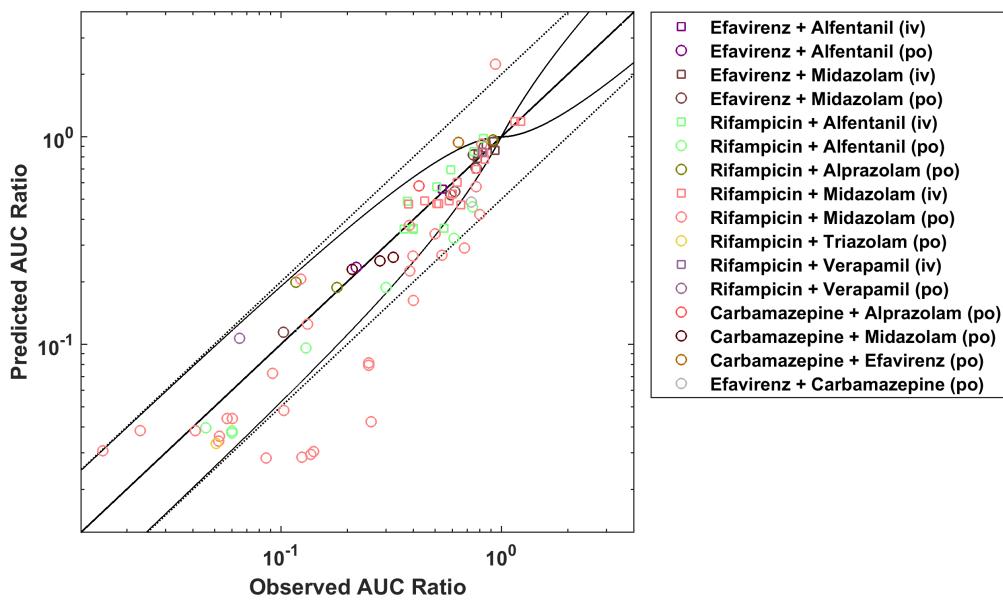
AUC	Number	Ratio [%]
Points total	164	-
Points within Guest et al.	118	71.9512
Points within 2-fold	145	88.4146

CMAX	Number	Ratio [%]
Points total	111	-
Points within Guest et al.	63	56.7568
Points within 2-fold	101	90.991

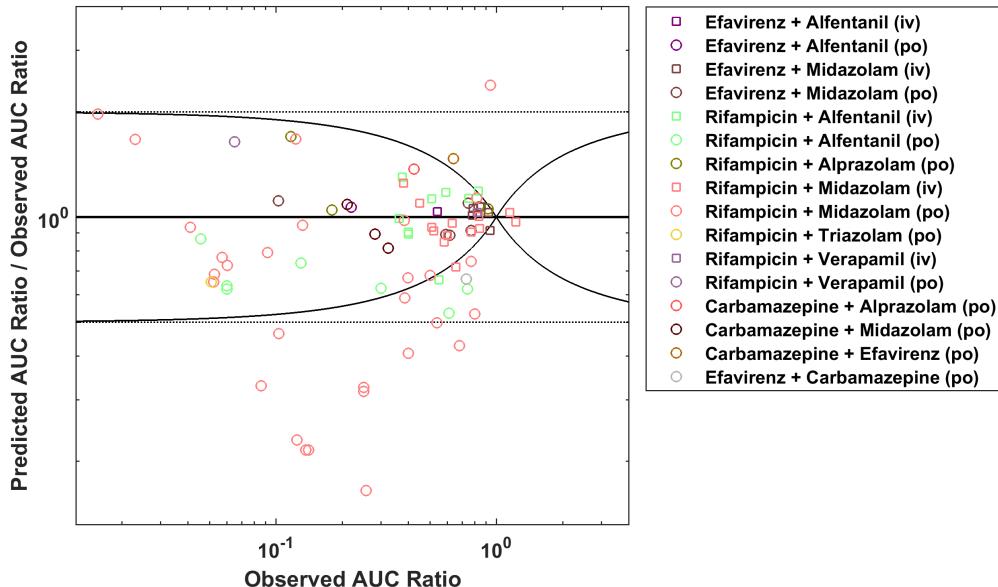
DataID	Perpetrator	Victim	Predicted AUC Ratio	Observed AUC Ratio	Pred/Obs AUC Ratio	Predicted CMAX Ratio	Observed CMAX Ratio	Pred/Obs CMAX Ratio	Reference
959	Carbamazepine, 200/400 mg, PO, MD	Efavirenz, PO	0.94153	0.64	1.4711	0.95608	0.79	1.2102	Ji 2008
465	Erythromycin, 500 mg, PO, MD	Carbamazepine, PO	1.6758	1.3196	1.2699	1.0627	0.96154	1.1052	Barzaghi 1987
1157	Erythromycin, 250 mg, PO, MD QID (3 days)	Carbamazepine, PO	1.2414	1.273	0.97521	1.1782	1.0927	1.0783	Miles 1989
1158	Erythromycin, 250 mg, PO, MD QID (3 days)	Carbamazepine, PO	1.2477	1.4233	0.87662	1.1802	0.99793	1.1826	Miles 1989
1154	Erythromycin, 250 mg, PO, MD	Carbamazepine, PO	1.4634	1.2397	1.1804	1.0467	-	-	Wong 1983
900	Cimetidine, 300 mg, PO, MD	Carbamazepine, PO	1.0758	1.2548	0.85737	1.0087	-	-	Dalton 1985a
961	Efavirenz, 600 mg, PO, MD	Carbamazepine, PO	0.48519	0.73	0.66464	0.5797	0.8	0.72462	Ji 2008

Mechanism

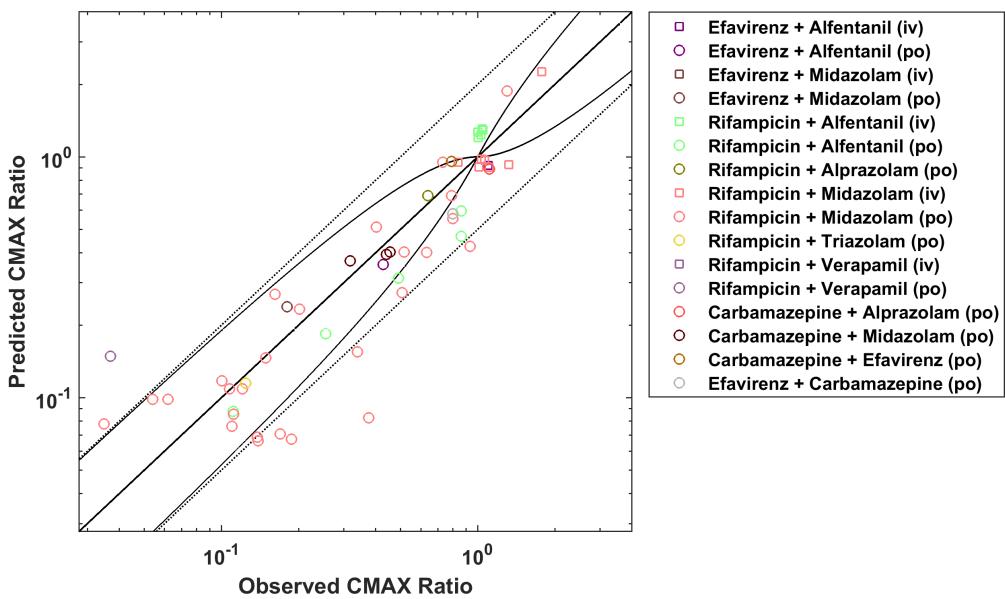
Induction



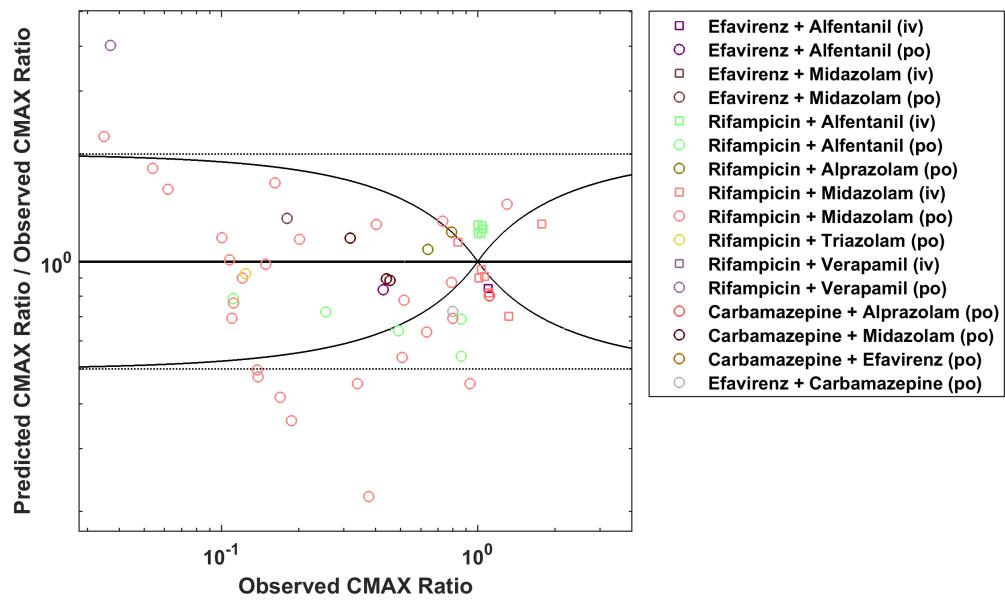
CYP3A4 DDI Induction



CYP3A4 DDI Induction



CYP3A4 DDI Induction



CYP3A4 DDI Induction

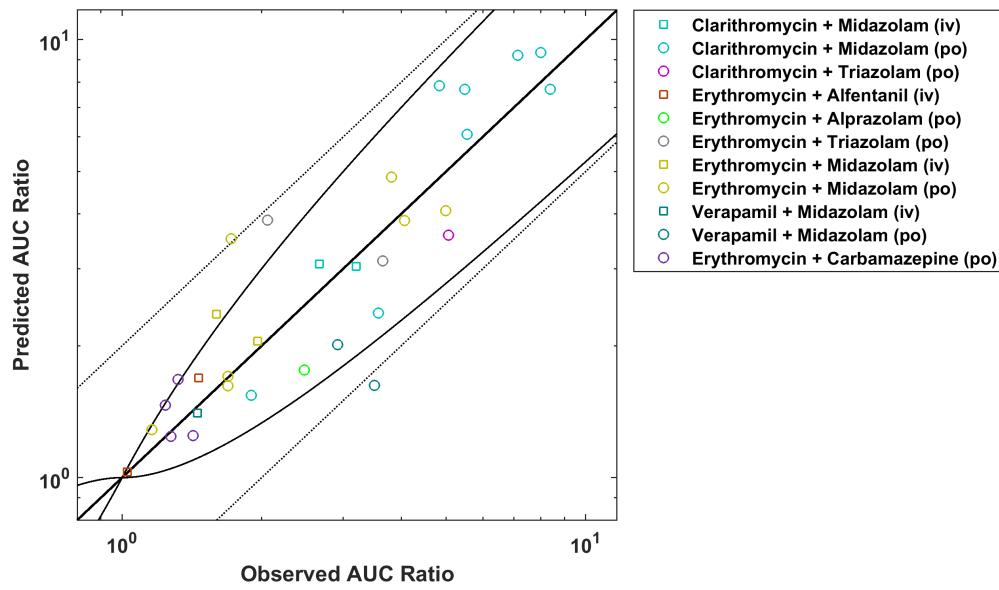
GMFE (AUC) = 1.421179

GMFE (CMAX) = 1.440137

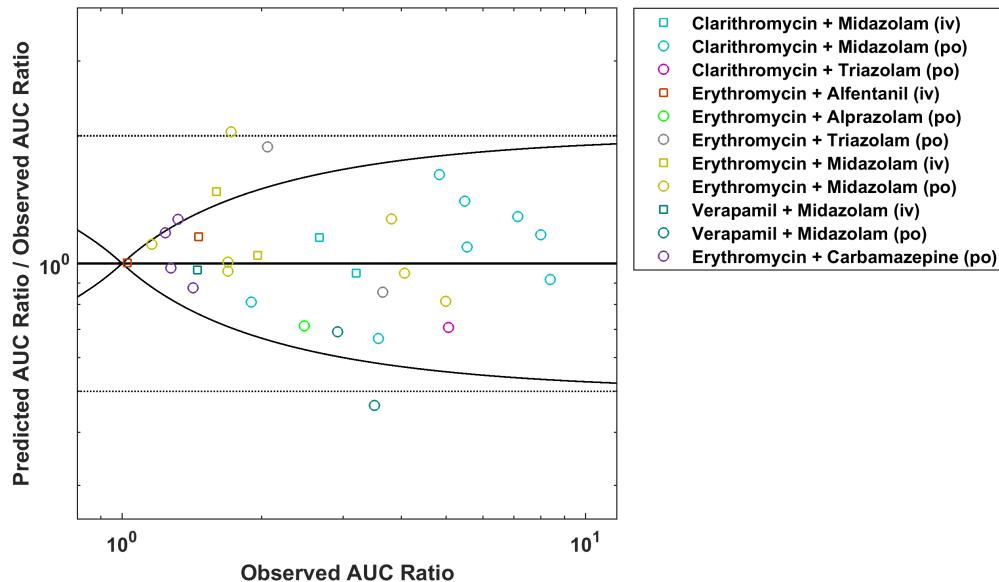
	AUC	Number	Ratio [%]
Points total	84		-
Points within Guest et al.	61		72.619
Points within 2-fold	72		85.7143

	CMAX	Number	Ratio [%]
Points total	55		-
Points within Guest et al.	24		43.6364
Points within 2-fold	46		83.6364

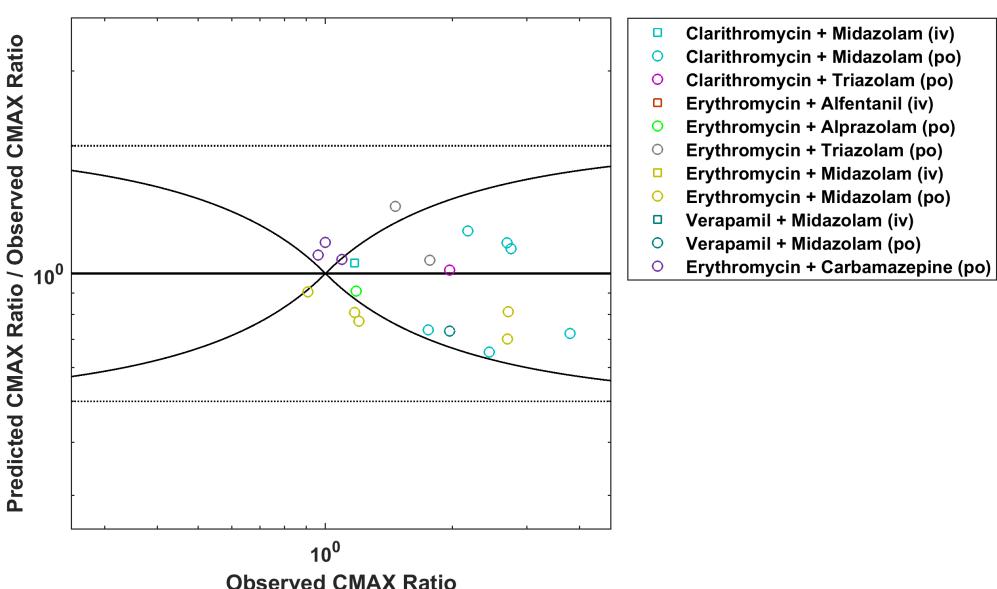
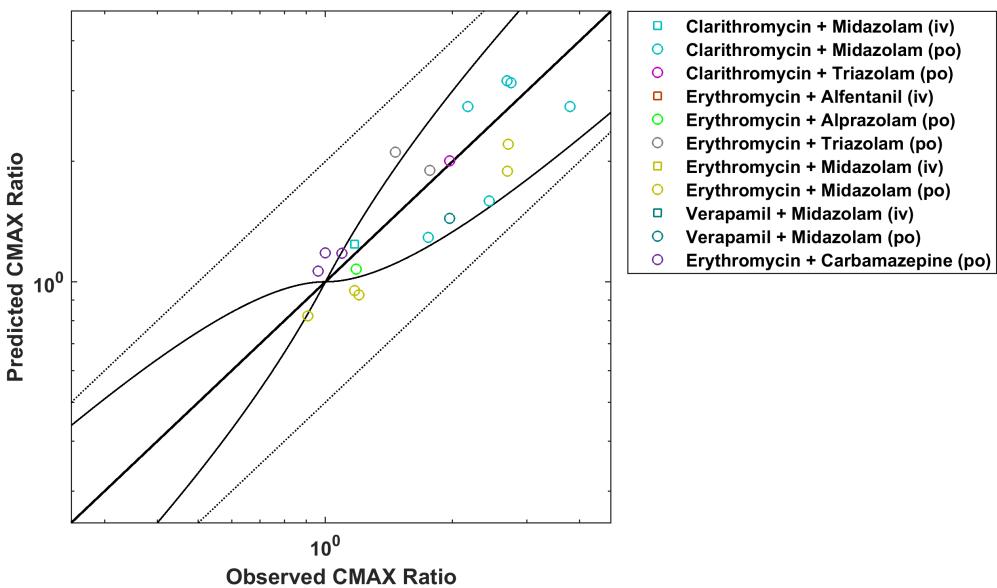
Mechanism based Inactivation



CYP3A4 DDI Mechanism based Inactivation



CYP3A4 DDI Mechanism based Inactivation



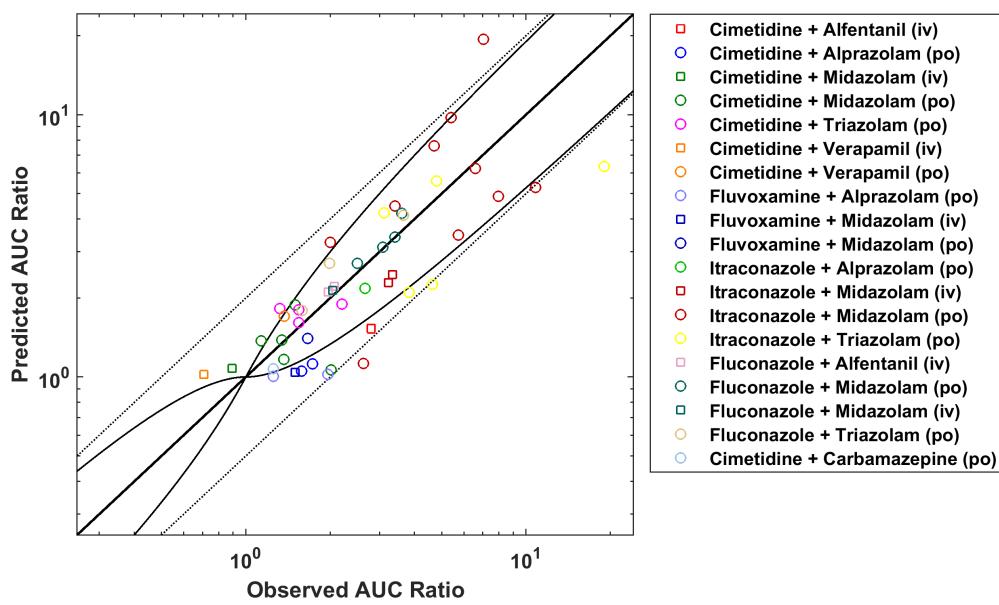
GMFE (AUC) = 1.259297

GMFE (CMAX) = 1.220389

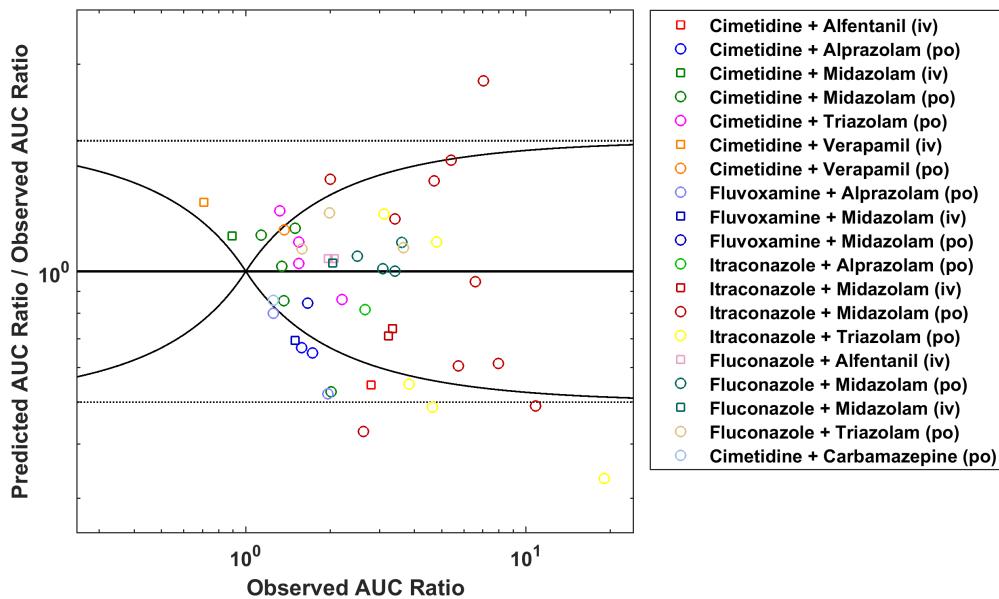
	AUC	Number	Ratio [%]
Points total		32	-
Points within Guest et al.		27	84.375
Points within 2-fold		30	93.75

	CMAX	Number	Ratio [%]
Points total		20	-
Points within Guest et al.		14	70
Points within 2-fold		20	100

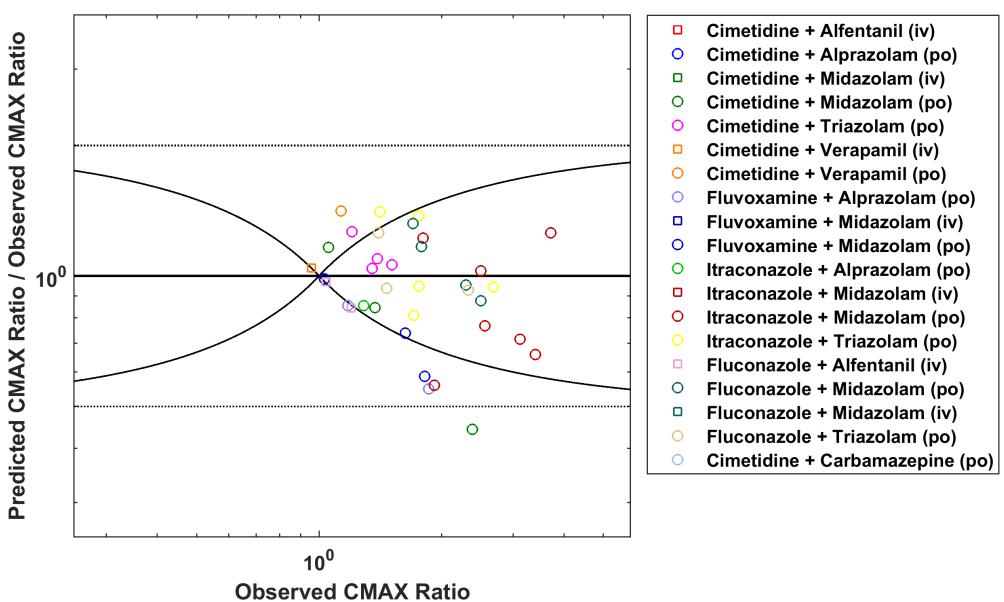
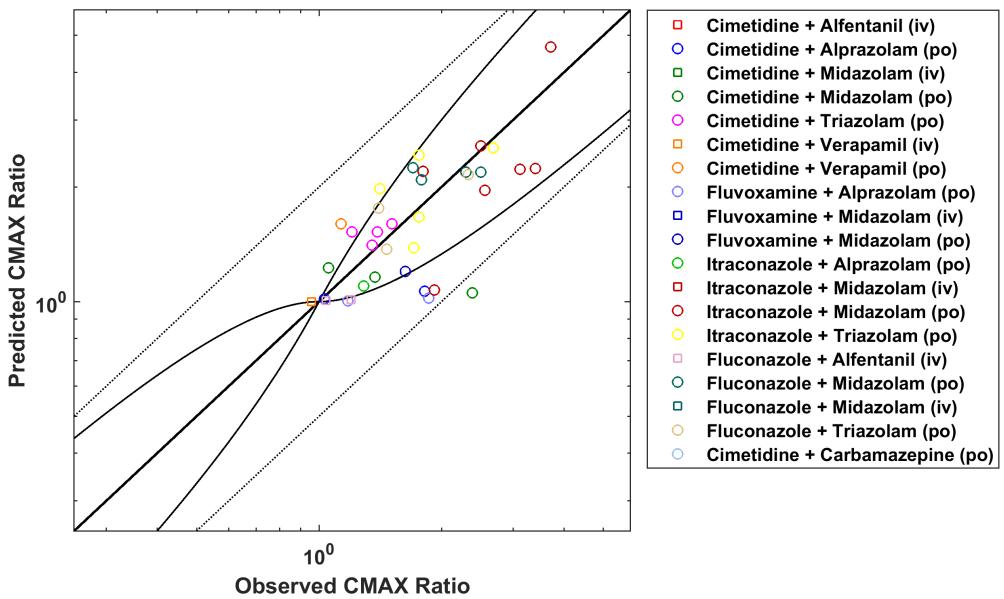
Reversible Inhibition



CYP3A4 DDI Reversible Inhibition



CYP3A4 DDI Reversible Inhibition



GMFE (AUC) = 1.391674

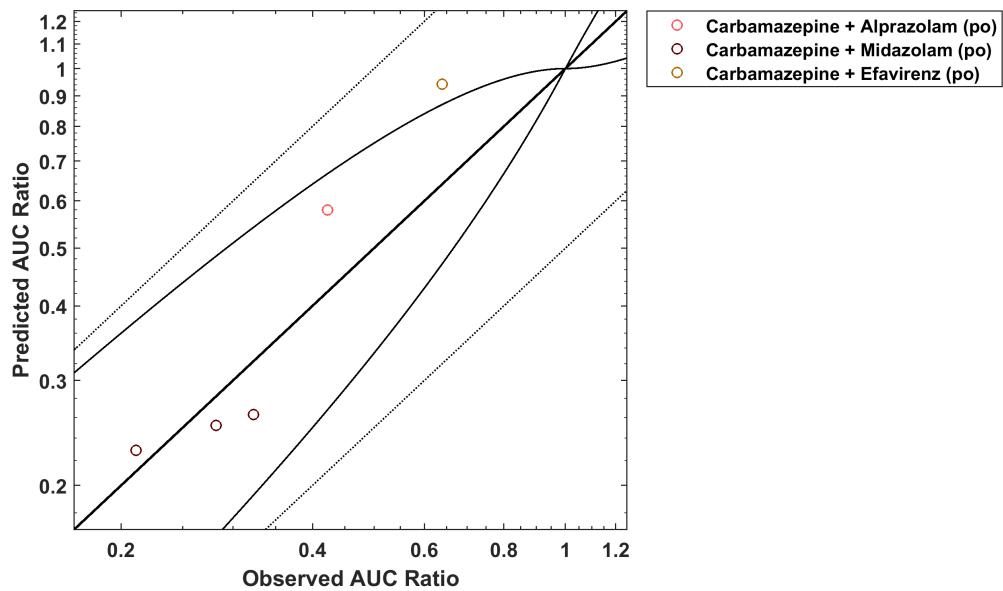
GMFE (CMAX) = 1.246966

	AUC	Number	Ratio [%]
Points total		48	-
Points within Guest et al.		30	62.5
Points within 2-fold		43	89.5833

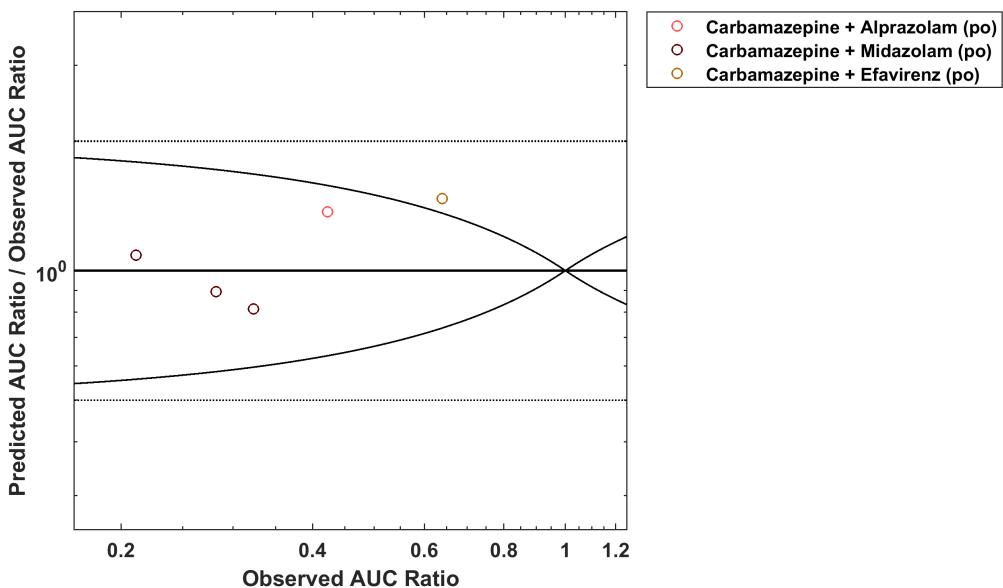
	CMAX	Number	Ratio [%]
Points total		36	-
Points within Guest et al.		25	69.4444
Points within 2-fold		35	97.2222

Perpetrator

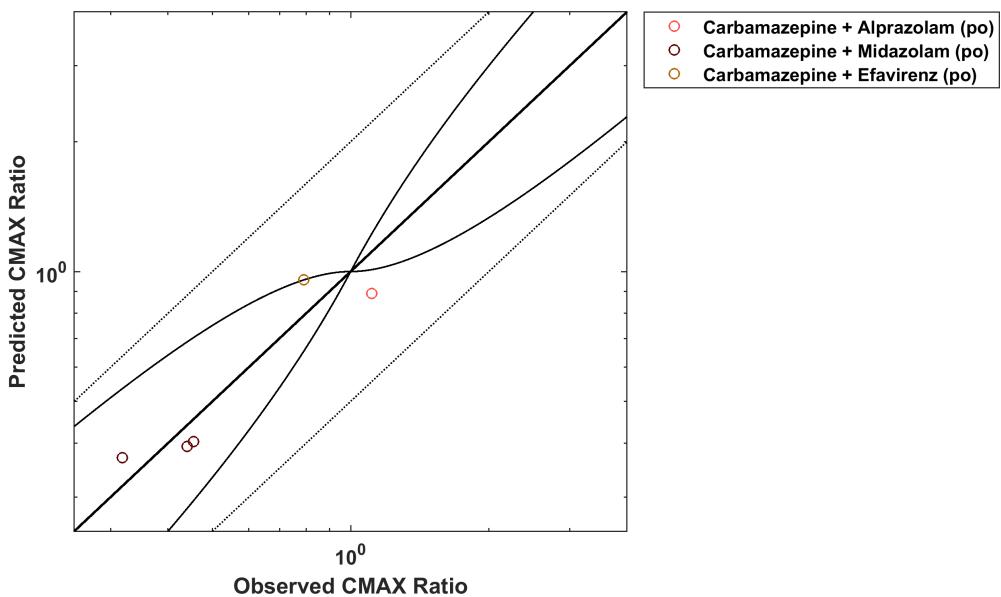
Carbamazepine



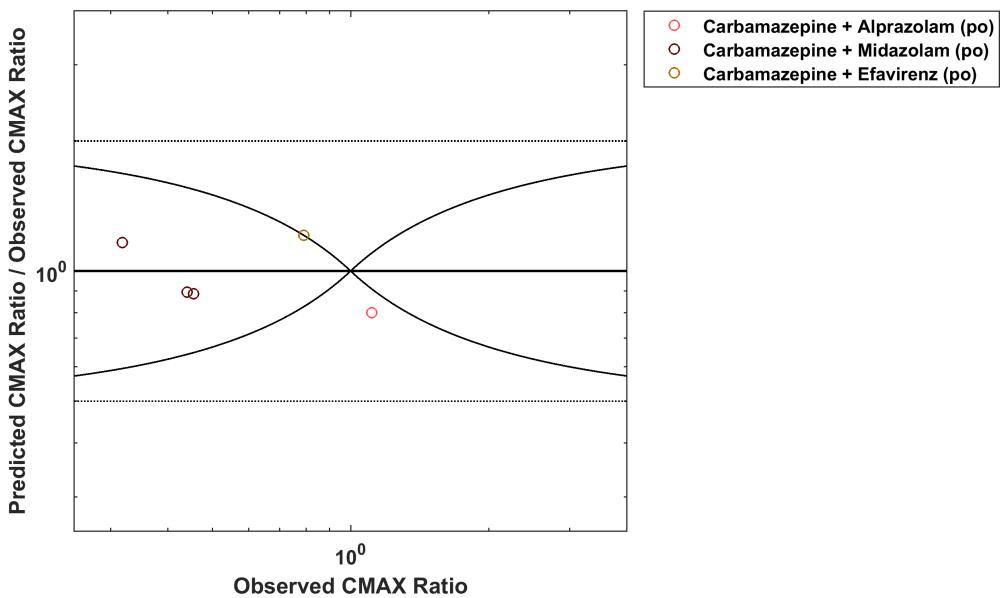
CYP3A4 DDI Carbamazepine



CYP3A4 DDI Carbamazepine



CYP3A4 DDI Carbamazepine



CYP3A4 DDI Carbamazepine

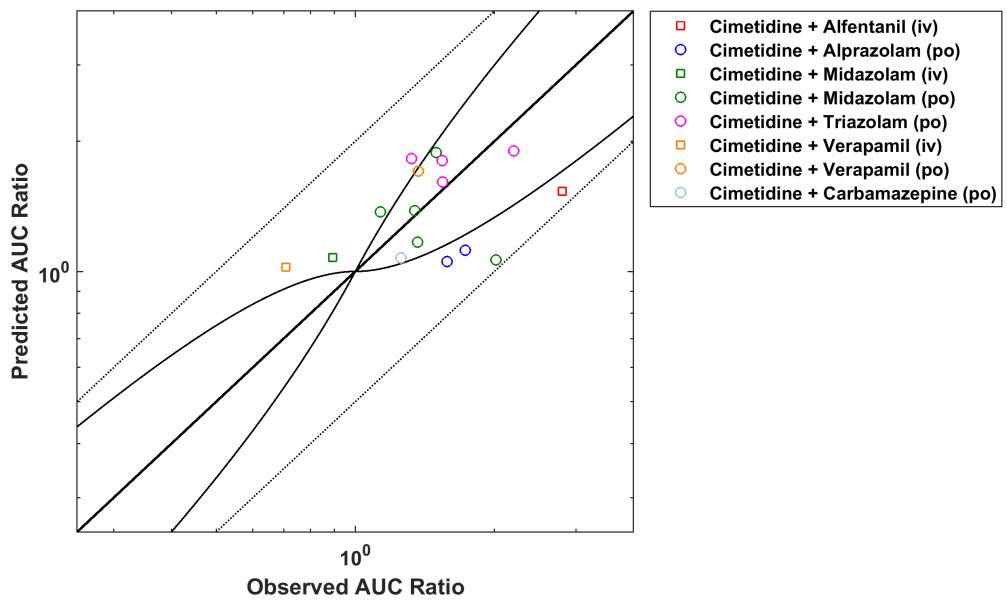
GMFE (AUC) = 1.246710

GMFE (CMAX) = 1.172747

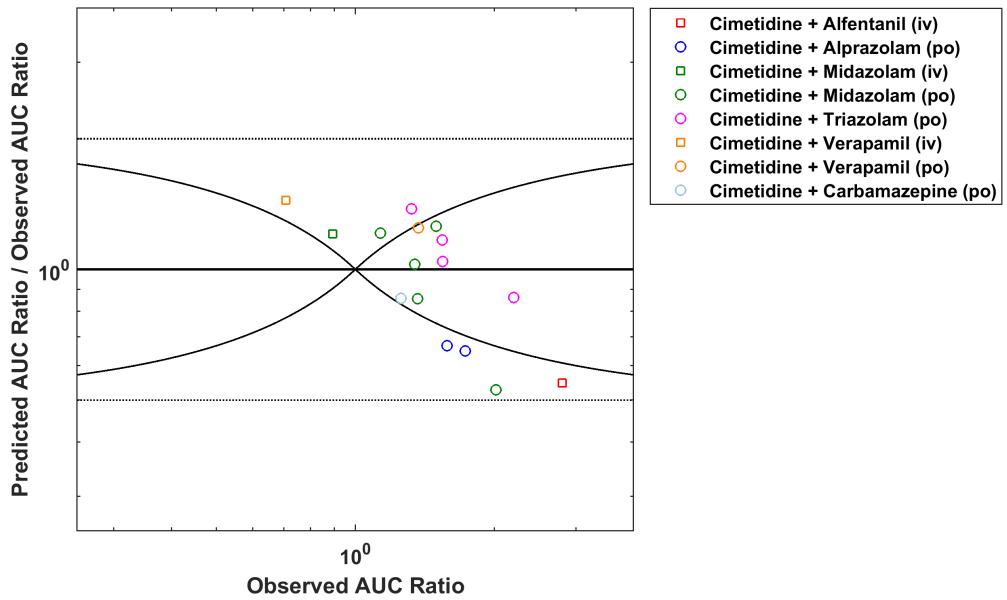
	AUC	Number	Ratio [%]
Points total		5	-
Points within Guest et al.		4	80
Points within 2-fold		5	100

	CMAX	Number	Ratio [%]
Points total		5	-
Points within Guest et al.		3	60
Points within 2-fold		5	100

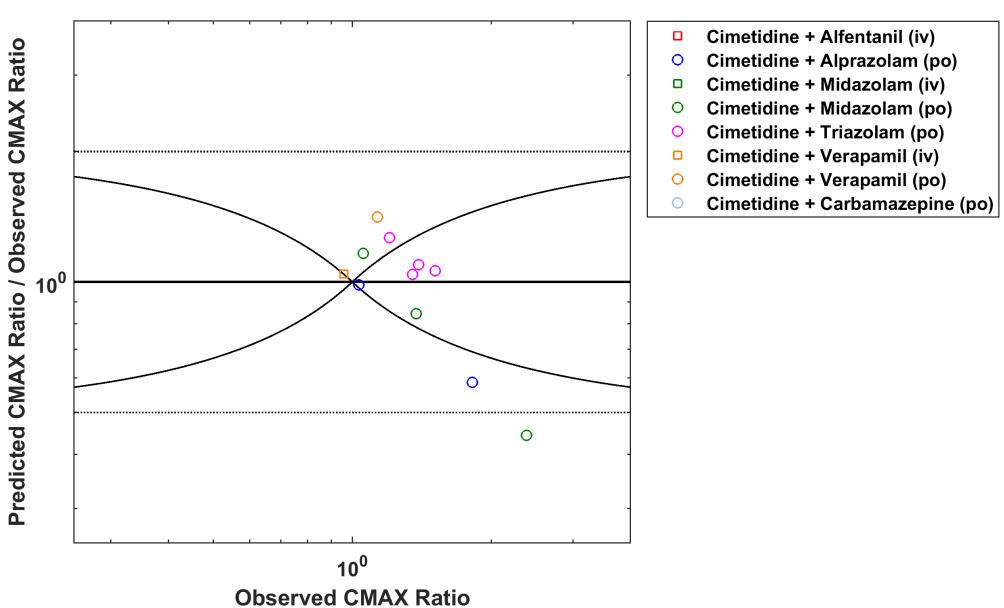
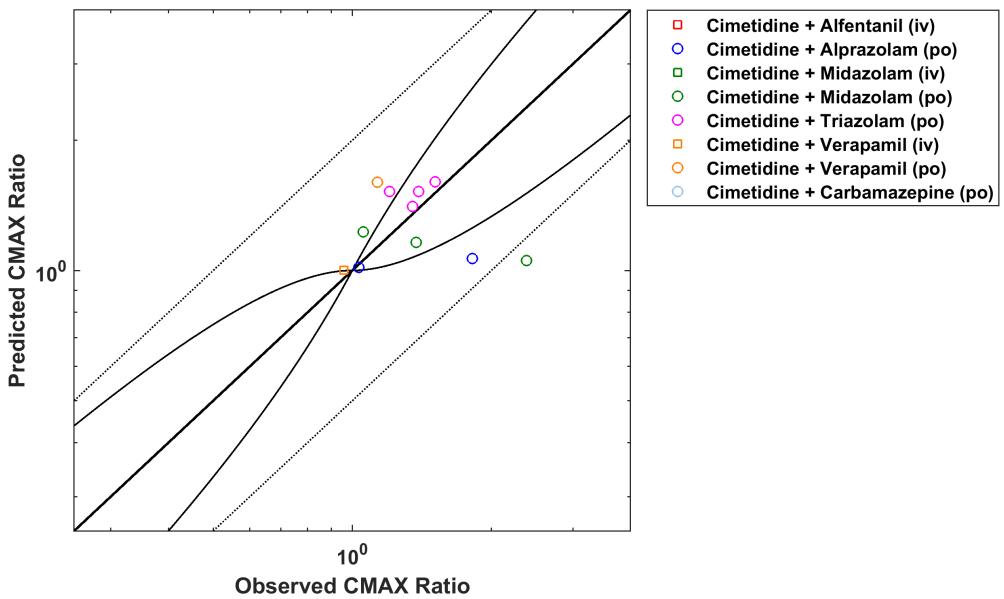
Cimetidine



CYP3A4 DDI Cimetidine



CYP3A4 DDI Cimetidine



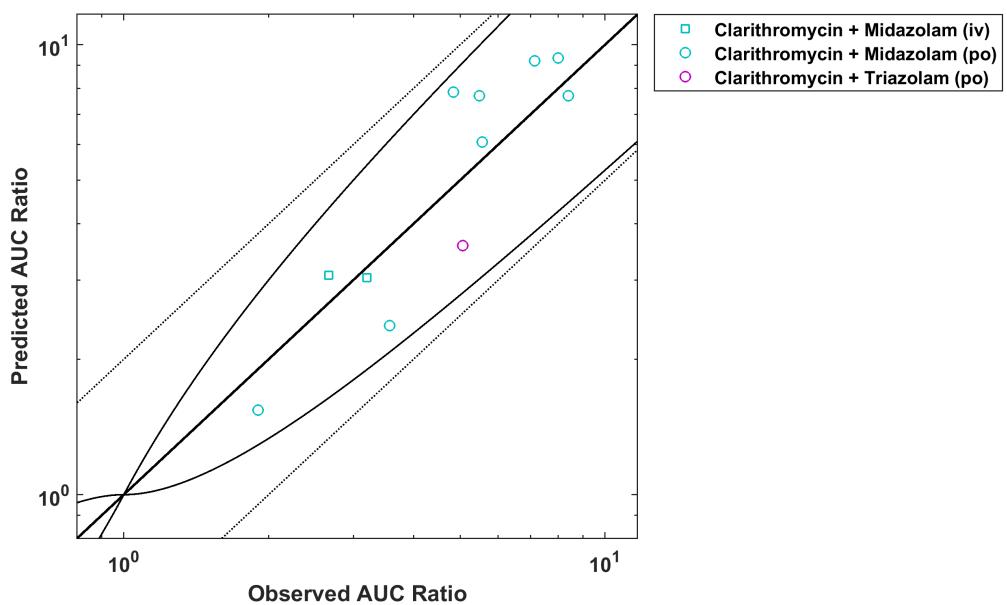
GMFE (AUC) = 1.306907

GMFE (CMAX) = 1.254689

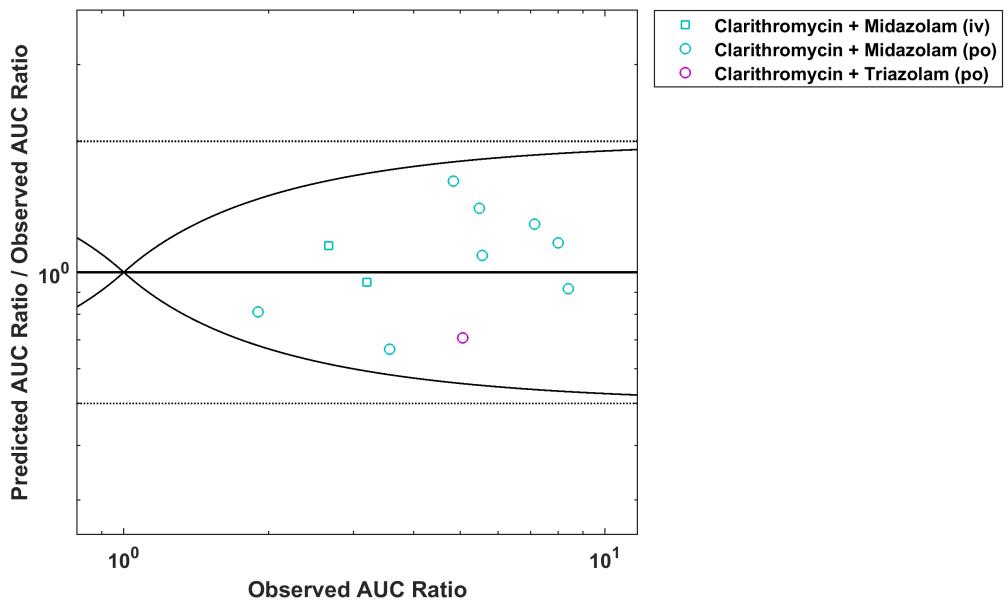
	AUC	Number	Ratio [%]
Points total		16	-
Points within Guest et al.		8	50
Points within 2-fold		16	100

	CMAX	Number	Ratio [%]
Points total		11	-
Points within Guest et al.		5	45.4545
Points within 2-fold		10	90.9091

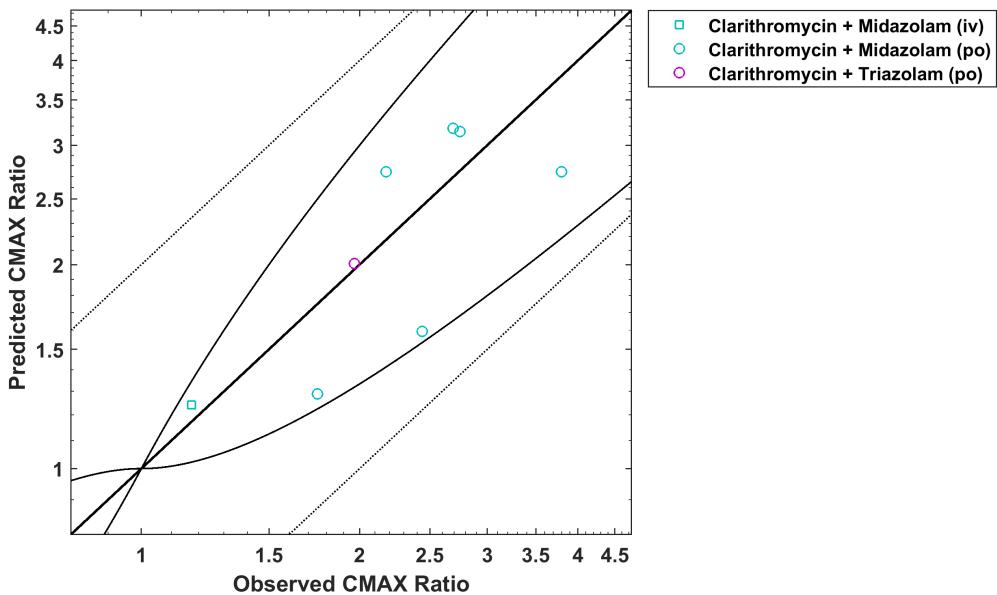
Clarithromycin



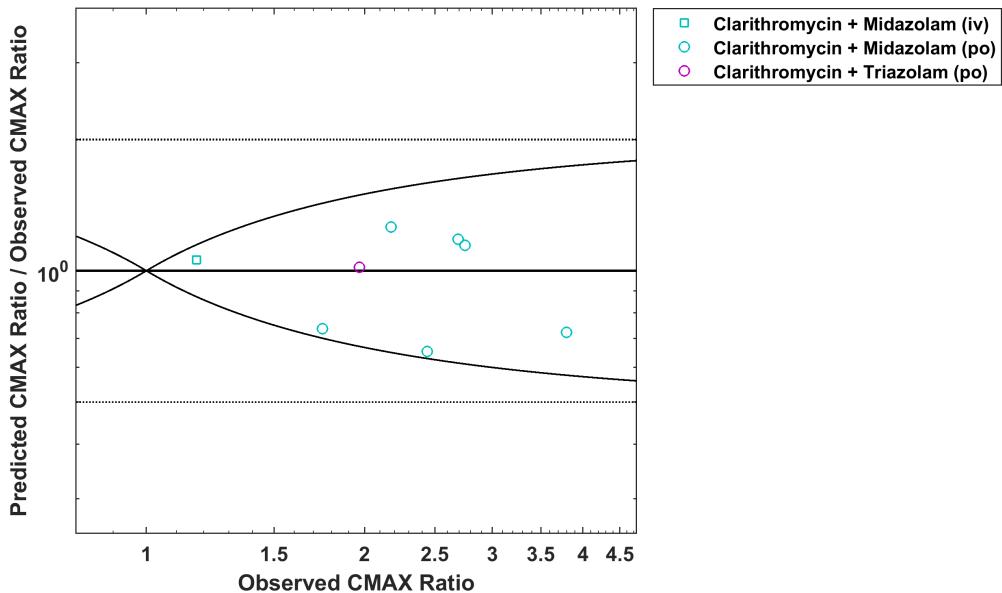
CYP3A4 DDI Clarithromycin



CYP3A4 DDI Clarithromycin



CYP3A4 DDI Clarithromycin



CYP3A4 DDI Clarithromycin

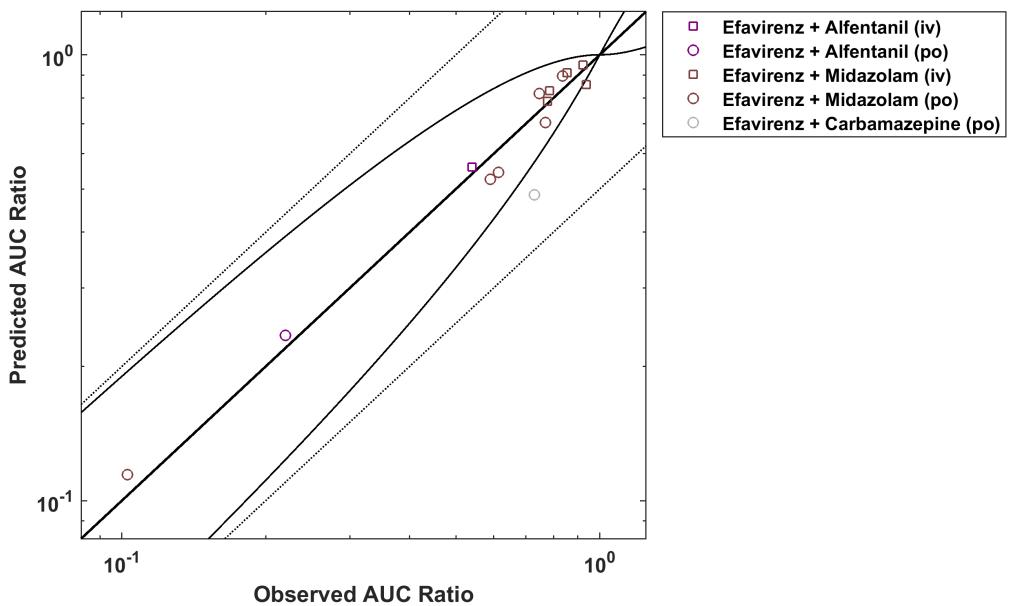
GMFE (AUC) = 1.262877

GMFE (CMAX) = 1.231376

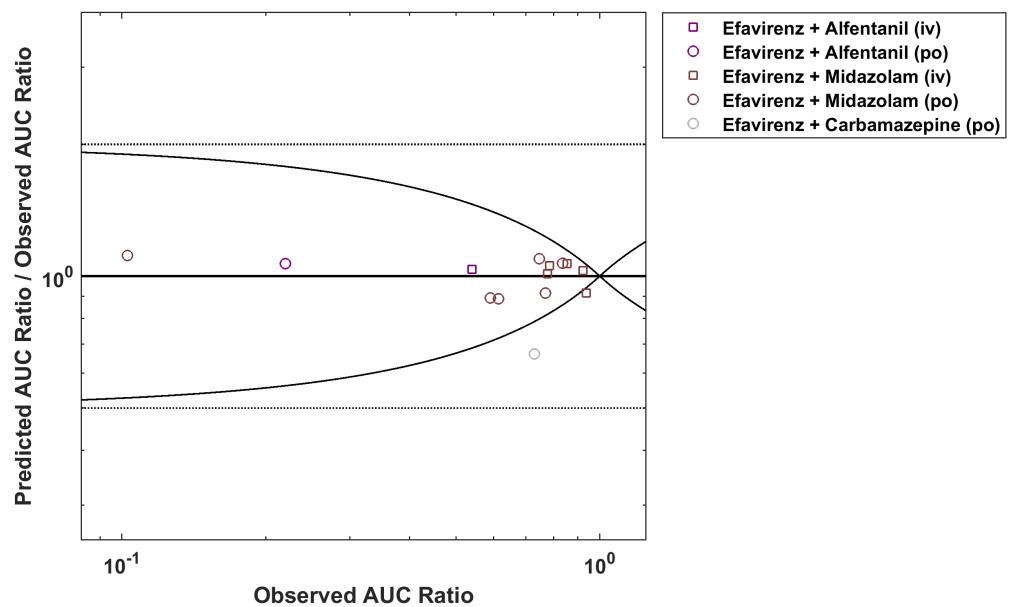
	AUC	Number	Ratio [%]
Points total		11	-
Points within Guest et al.		11	100
Points within 2-fold		11	100

	CMAX	Number	Ratio [%]
Points total		8	-
Points within Guest et al.		8	100
Points within 2-fold		8	100

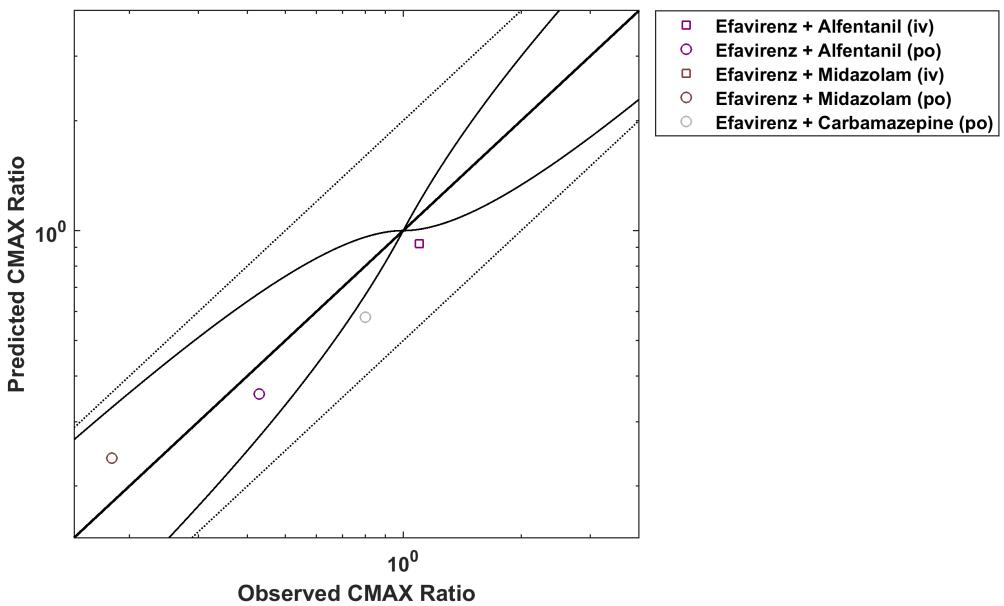
Efavirenz



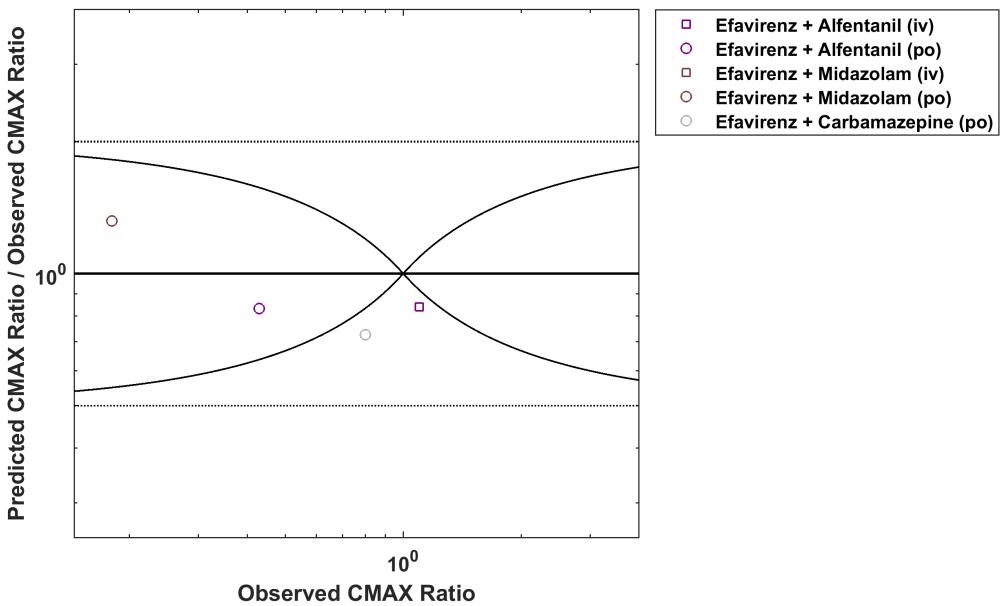
CYP3A4 DDI Efavirenz



CYP3A4 DDI Efavirenz



CYP3A4 DDI Efavirenz



CYP3A4 DDI Efavirenz

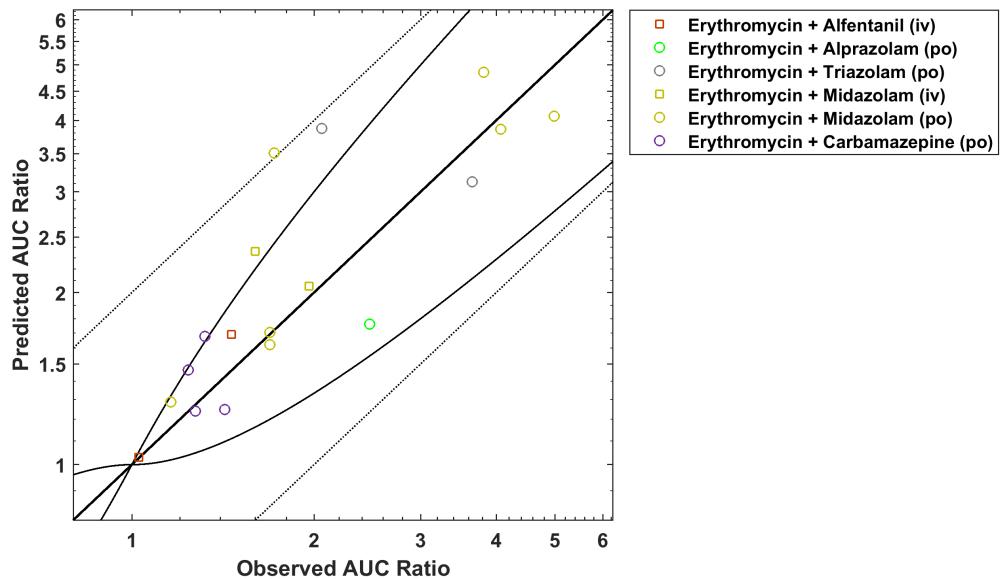
GMFE (AUC) = 1.101484

GMFE (CMAX) = 1.270173

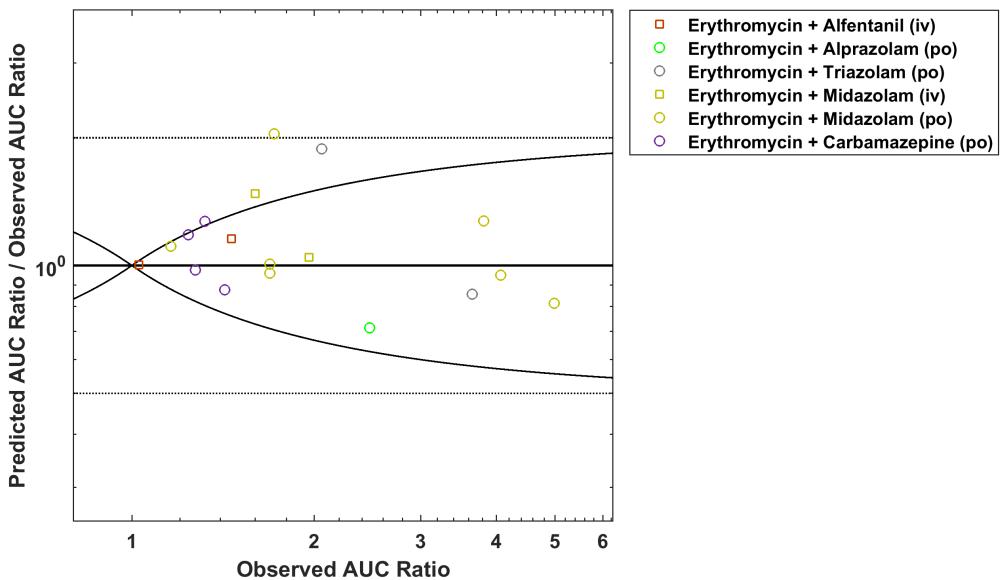
AUC	Number	Ratio [%]
Points total	14	-
Points within Guest et al.	12	85.7143
Points within 2-fold	14	100

CMAX	Number	Ratio [%]
Points total	4	-
Points within Guest et al.	2	50
Points within 2-fold	4	100

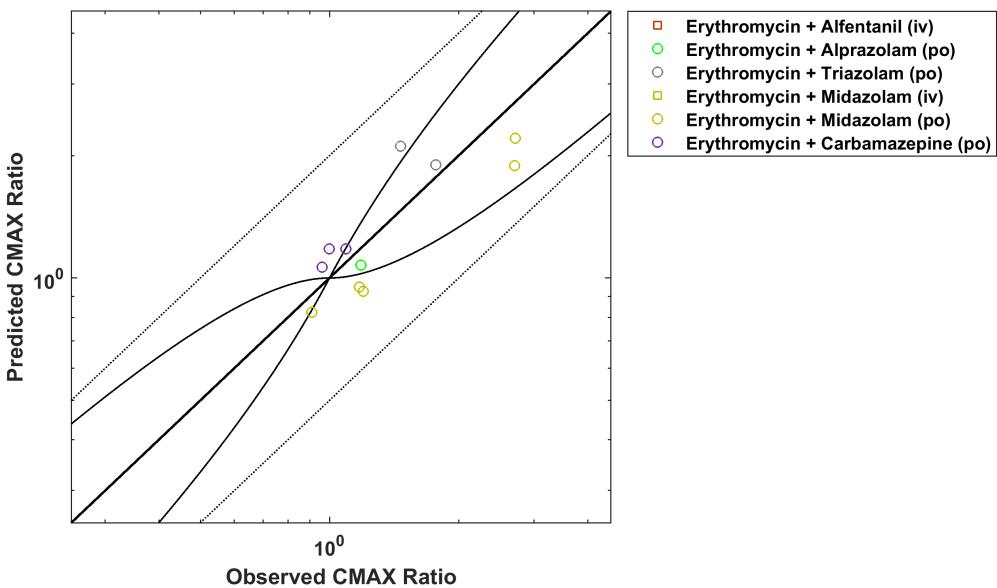
Erythromycin



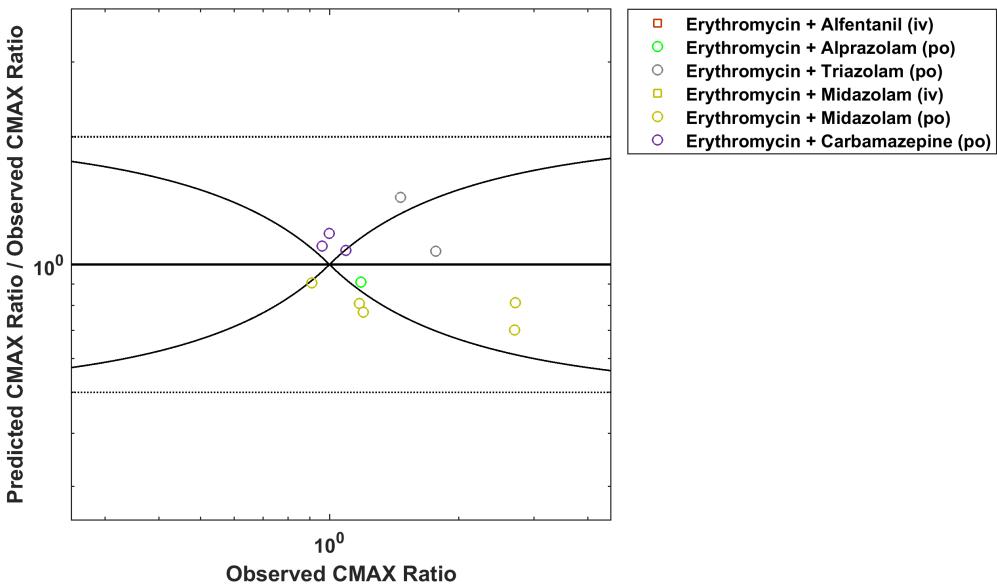
CYP3A4 DDI Erythromycin



CYP3A4 DDI Erythromycin



CYP3A4 DDI Erythromycin



CYP3A4 DDI Erythromycin

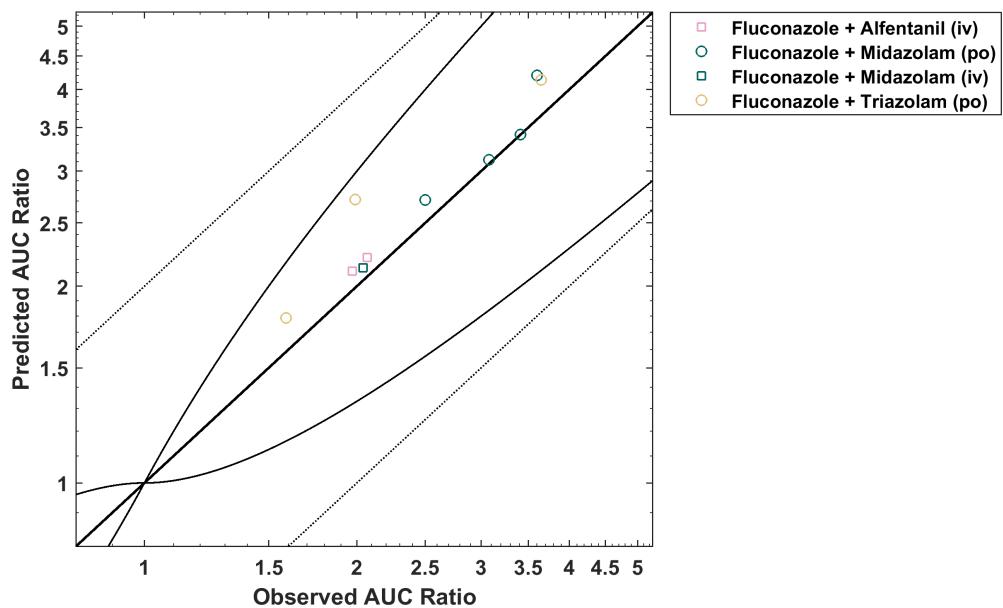
GMFE (AUC) = 1.223770

GMFE (CMAX) = 1.200069

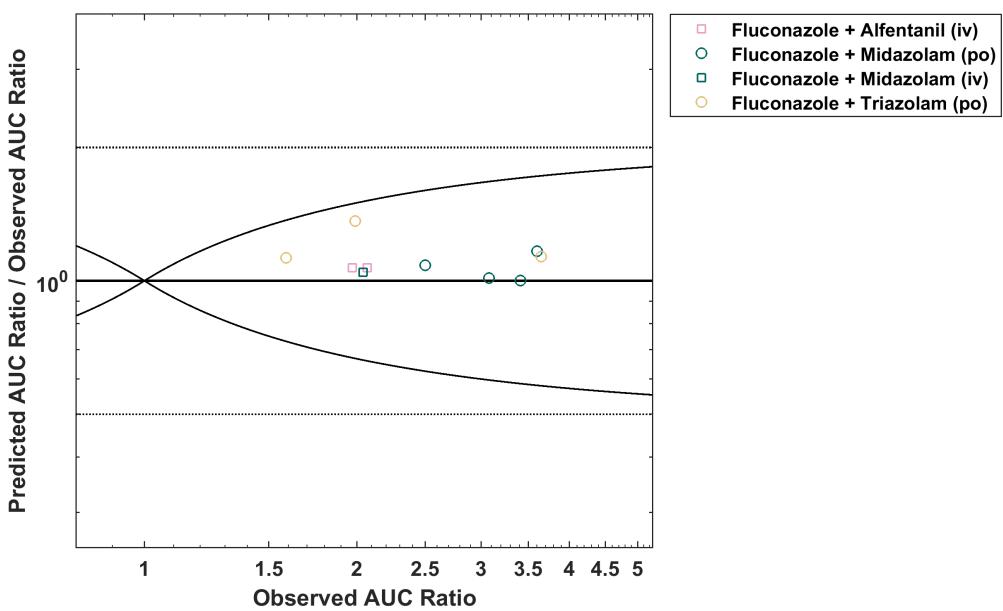
	AUC	Number	Ratio [%]
Points total		18	-
Points within Guest et al.		14	77.7778
Points within 2-fold		17	94.4444

	CMAX	Number	Ratio [%]
Points total		11	-
Points within Guest et al.		5	45.4545
Points within 2-fold		11	100

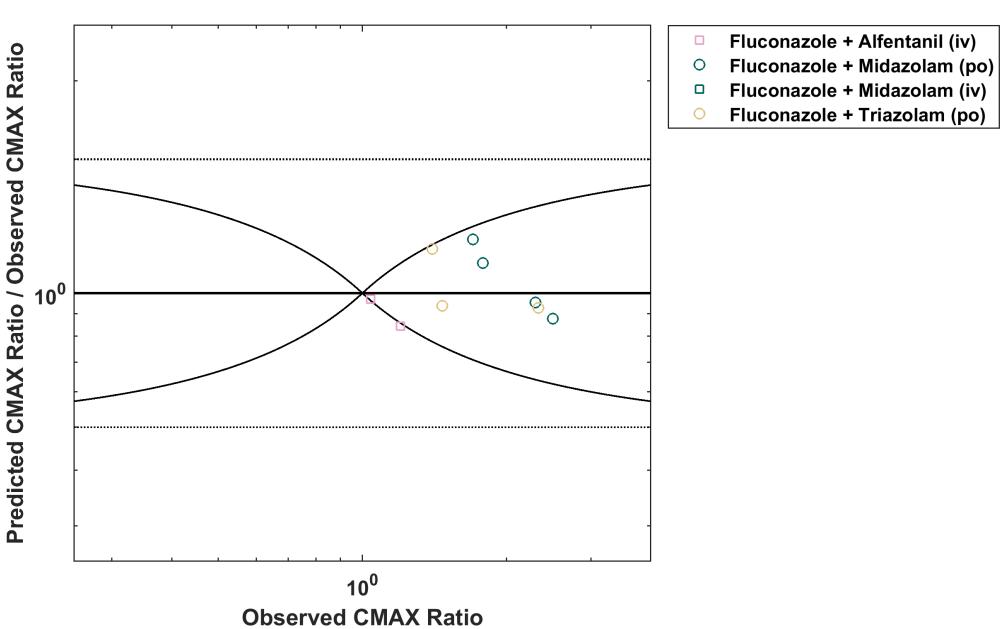
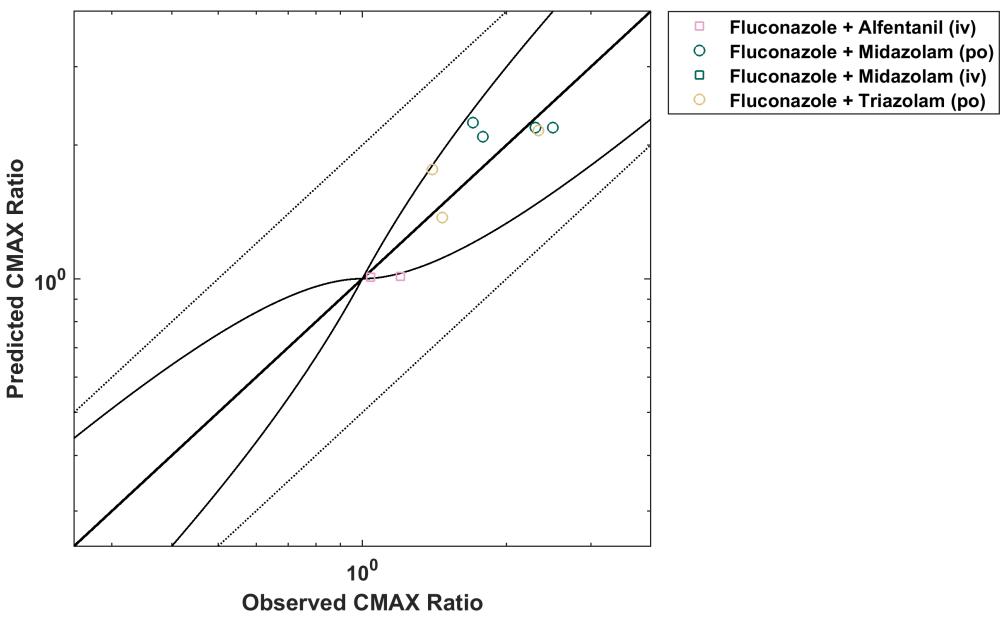
Fluconazole



CYP3A4 DDI Fluconazole



CYP3A4 DDI Fluconazole



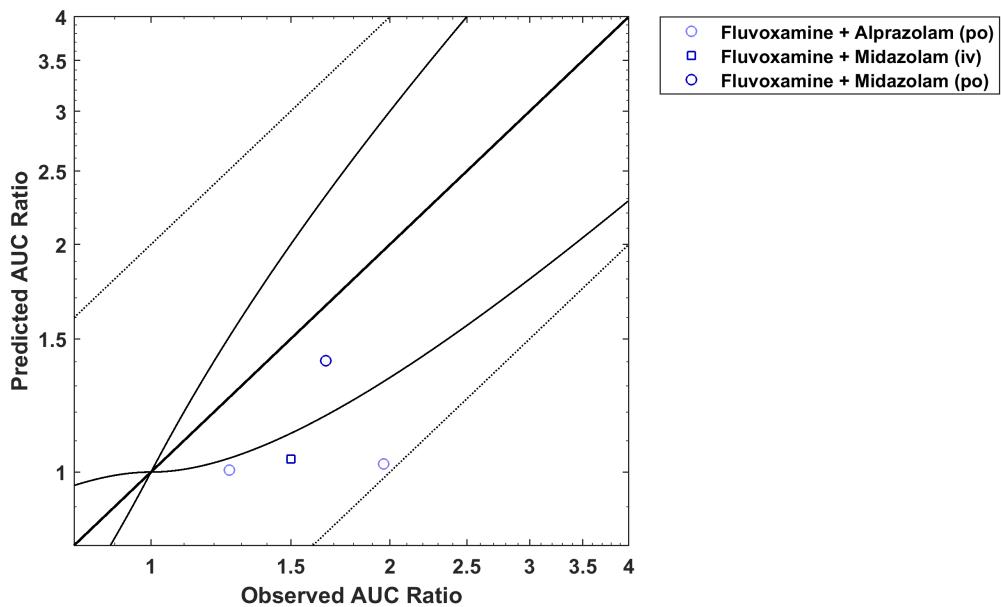
GMFE (AUC) = 1.103898

GMFE (CMAX) = 1.141234

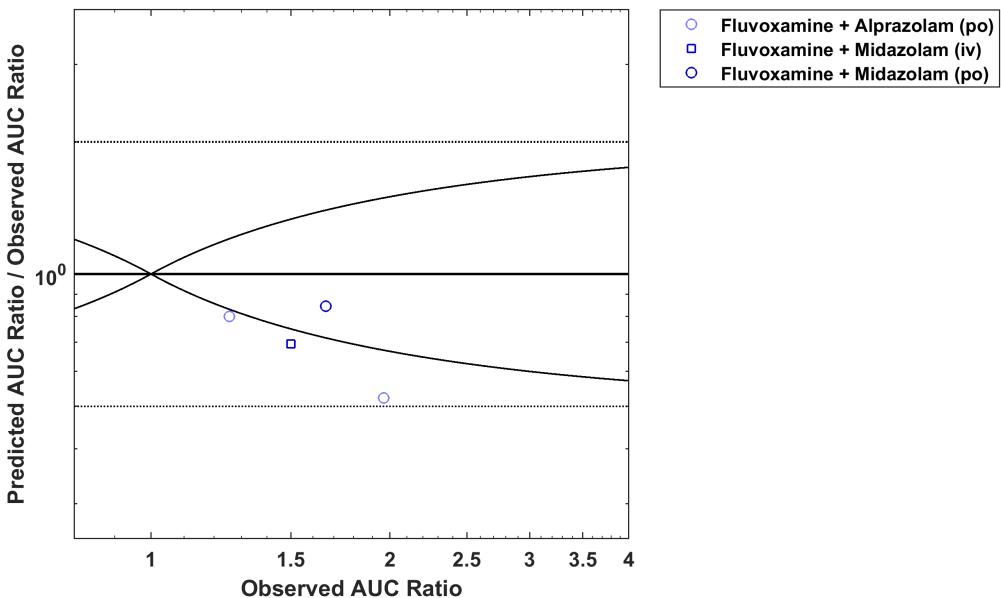
	AUC	Number	Ratio [%]
Points total		10	-
Points within Guest et al.		10	100
Points within 2-fold		10	100

	CMAX	Number	Ratio [%]
Points total		9	-
Points within Guest et al.		8	88.8889
Points within 2-fold		9	100

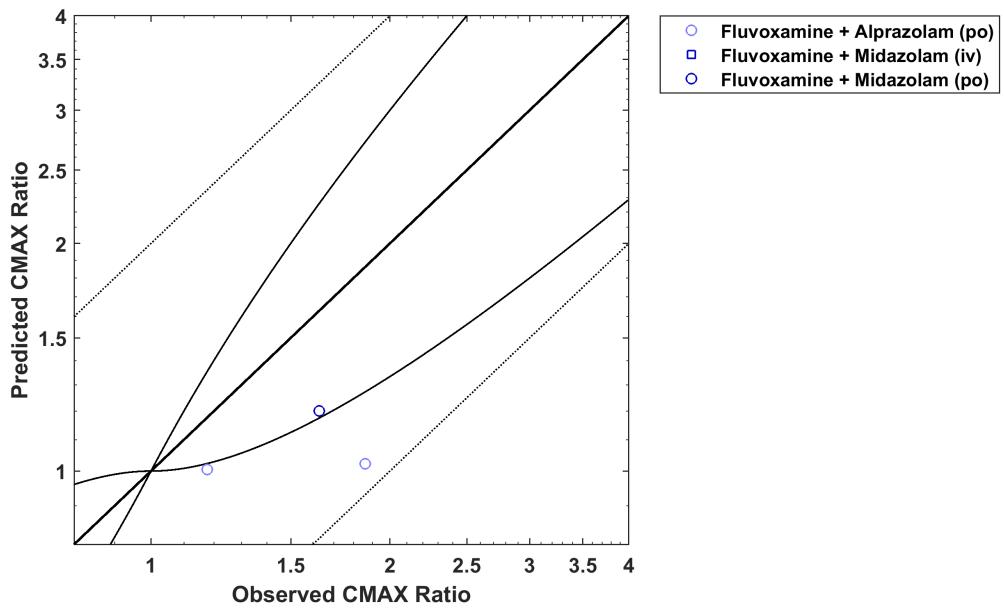
Fluvoxamine



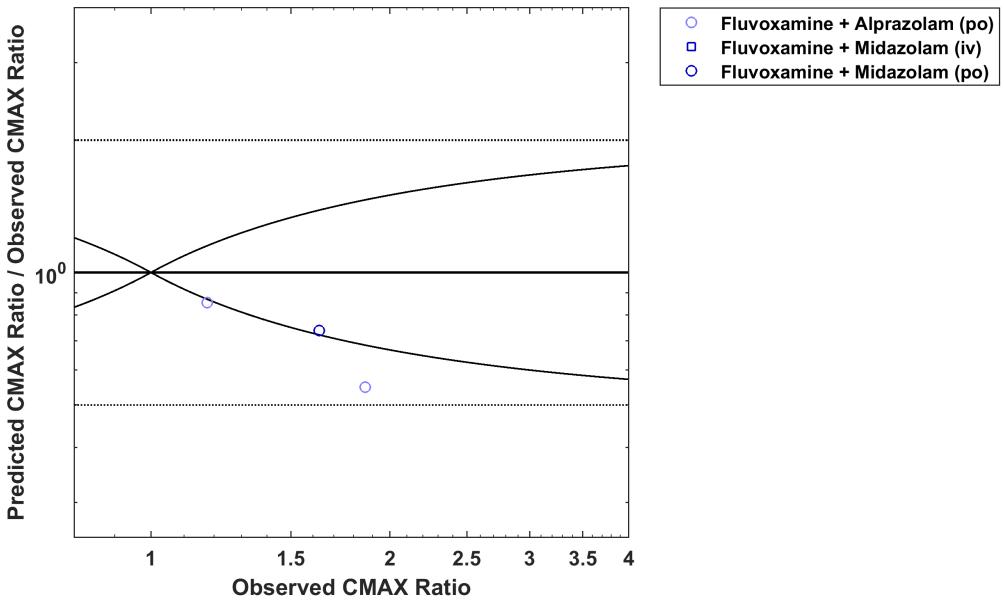
CYP3A4 DDI Fluvoxamine



CYP3A4 DDI Fluvoxamine



CYP3A4 DDI Fluvoxamine



CYP3A4 DDI Fluvoxamine

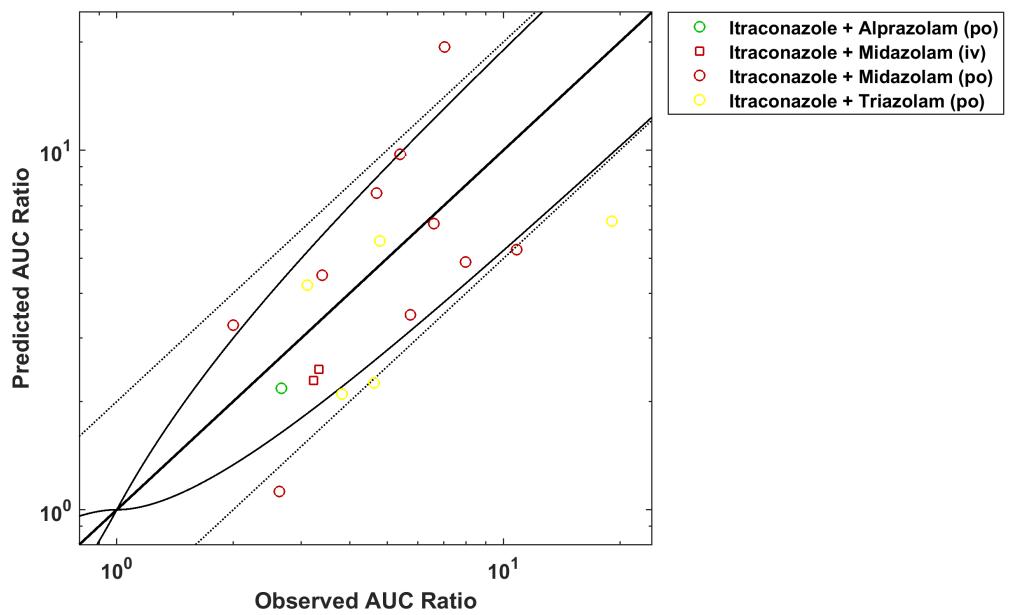
GMFE (AUC) = 1.420915

GMFE (CMAX) = 1.425106

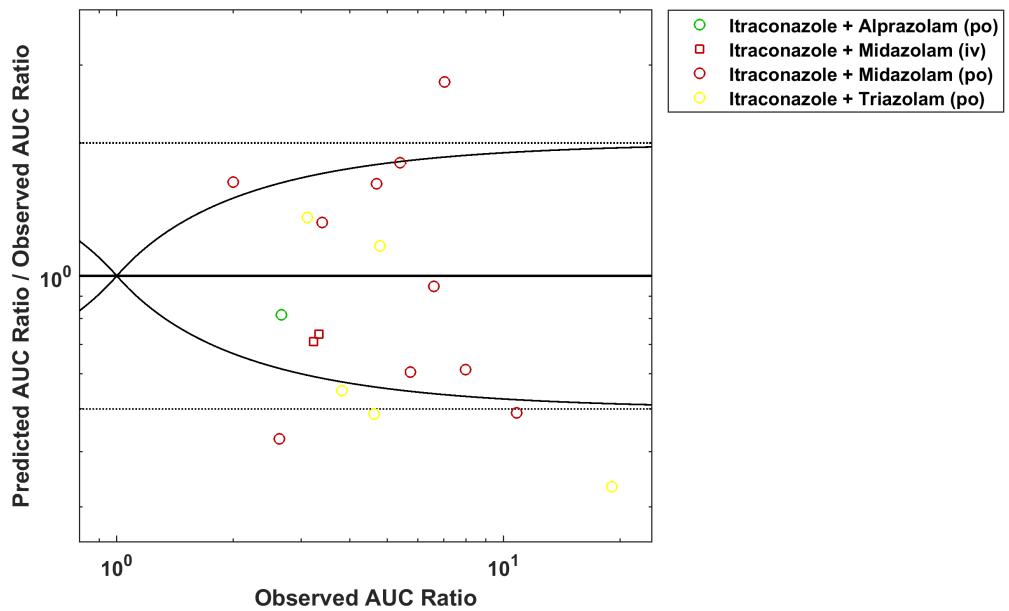
	AUC	Number	Ratio [%]
Points total		4	-
Points within Guest et al.		1	25
Points within 2-fold		4	100

	CMAX	Number	Ratio [%]
Points total		3	-
Points within Guest et al.		1	33.3333
Points within 2-fold		3	100

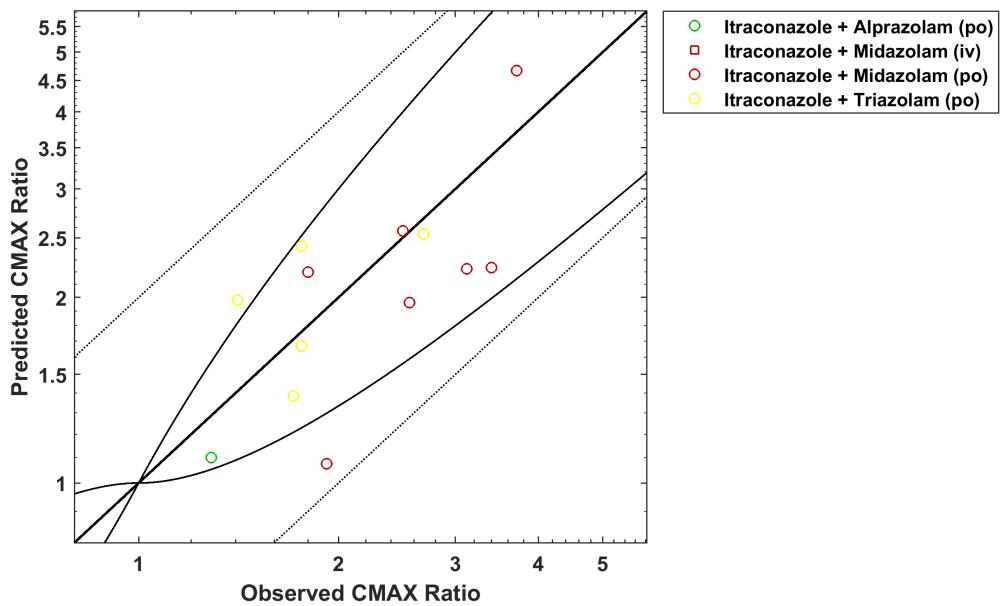
Itraconazole



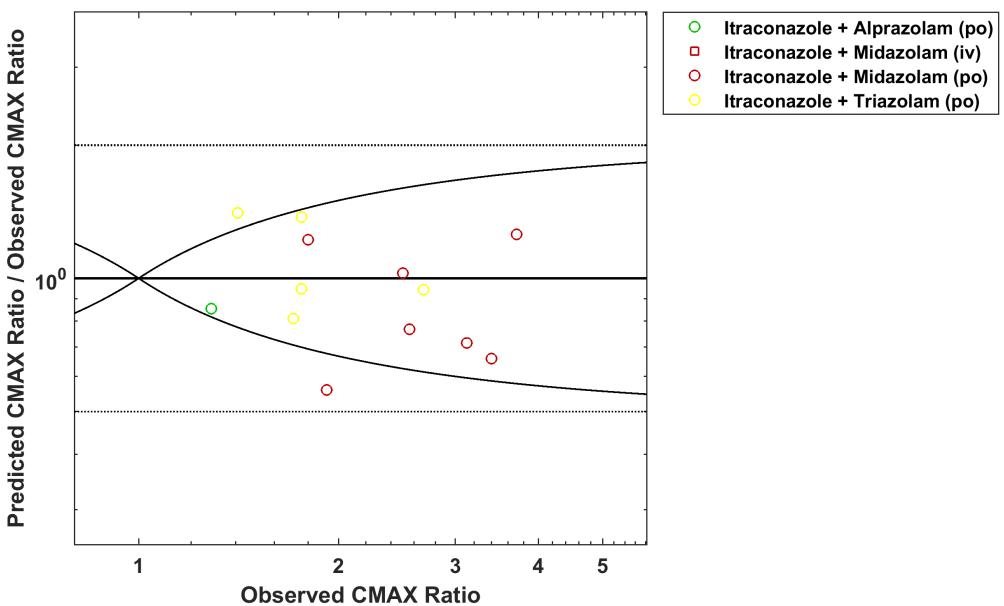
CYP3A4 DDI Itraconazole



CYP3A4 DDI Itraconazole



CYP3A4 DDI Itraconazole



CYP3A4 DDI Itraconazole

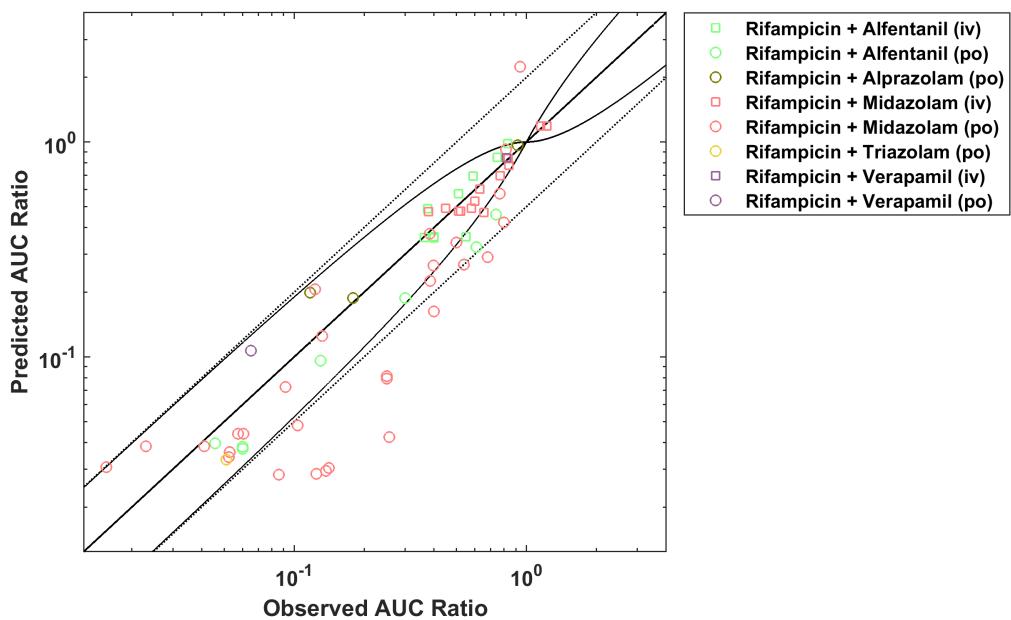
GMFE (AUC) = 1.666038

GMFE (CMAX) = 1.278918

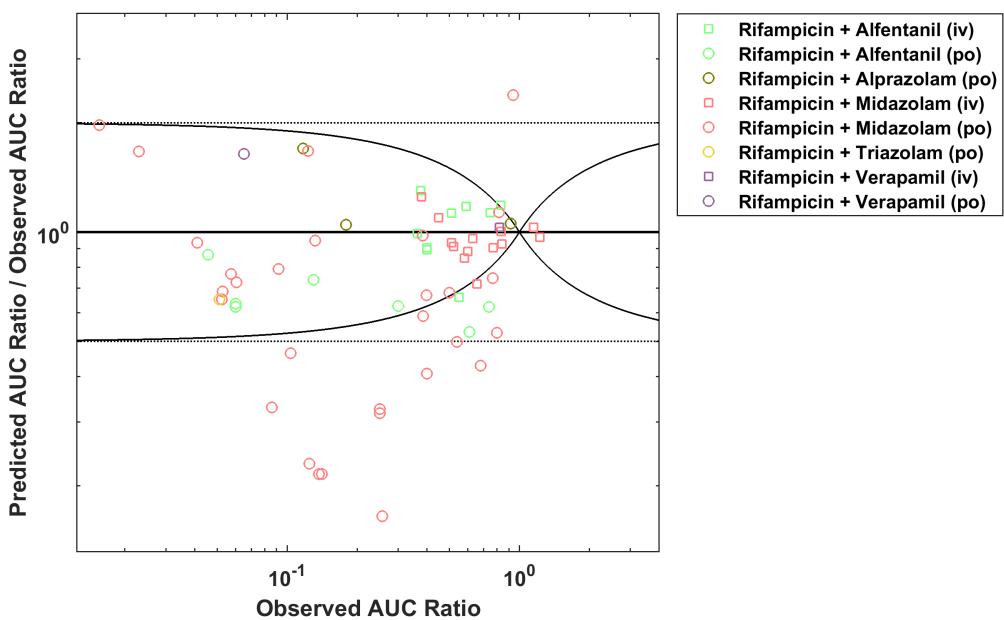
AUC	Number	Ratio [%]
Points total	18	-
Points within Guest et al.	11	61.1111
Points within 2-fold	13	72.2222

CMAX	Number	Ratio [%]
Points total	13	-
Points within Guest et al.	11	84.6154
Points within 2-fold	13	100

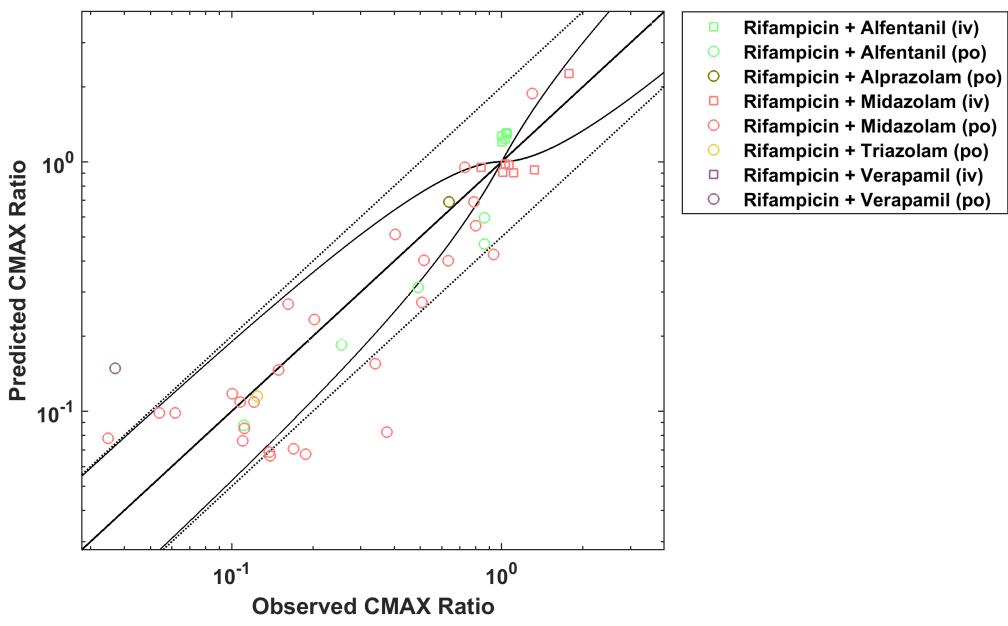
Rifampicin



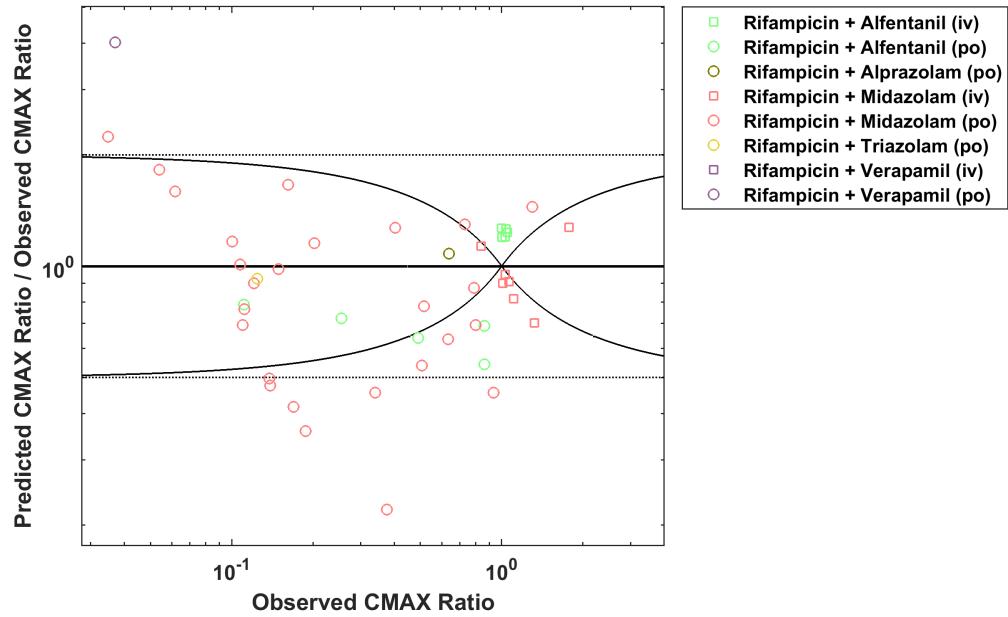
CYP3A4 DDI Rifampicin



CYP3A4 DDI Rifampicin



CYP3A4 DDI Rifampicin



CYP3A4 DDI Rifampicin

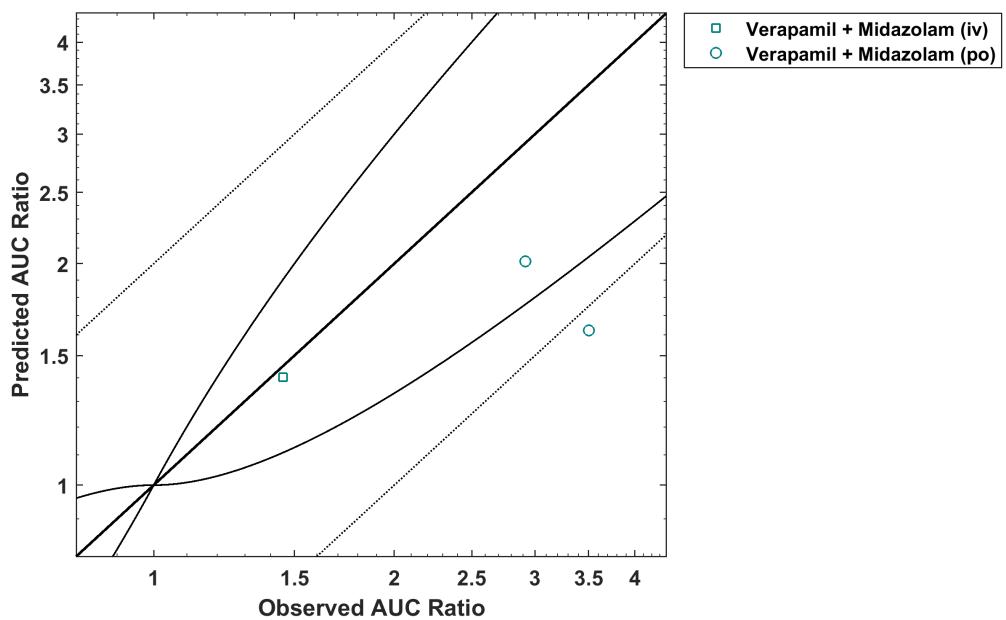
GMFE (AUC) = 1.516566

GMFE (CMAX) = 1.488820

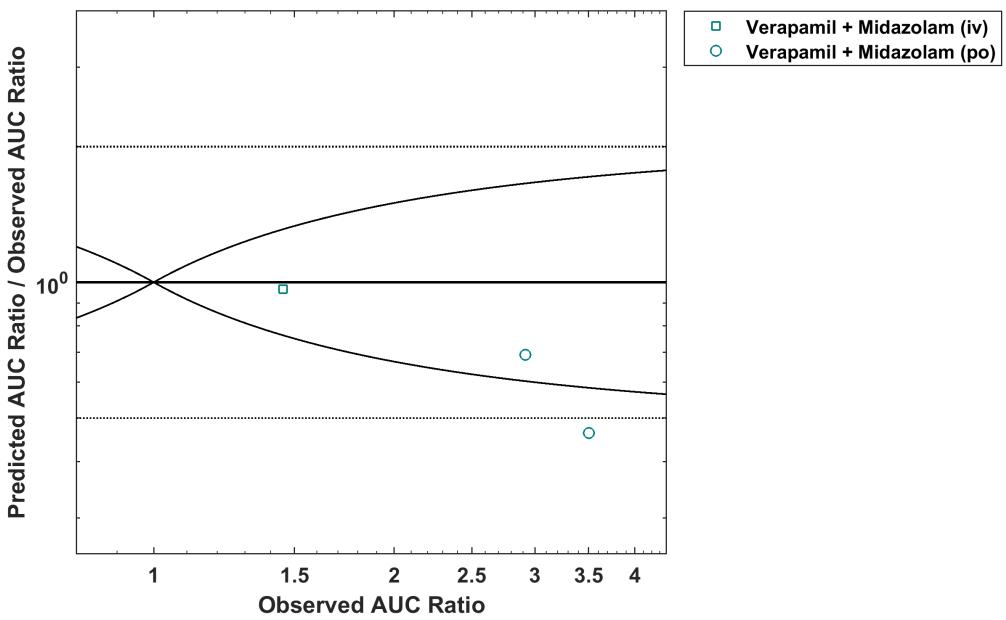
	AUC	Number	Ratio [%]
Points total	65	-	
Points within Guest et al.	45	69.2308	
Points within 2-fold	53	81.5385	

	CMAX	Number	Ratio [%]
Points total	46	-	
Points within Guest et al.	19	41.3043	
Points within 2-fold	37	80.4348	

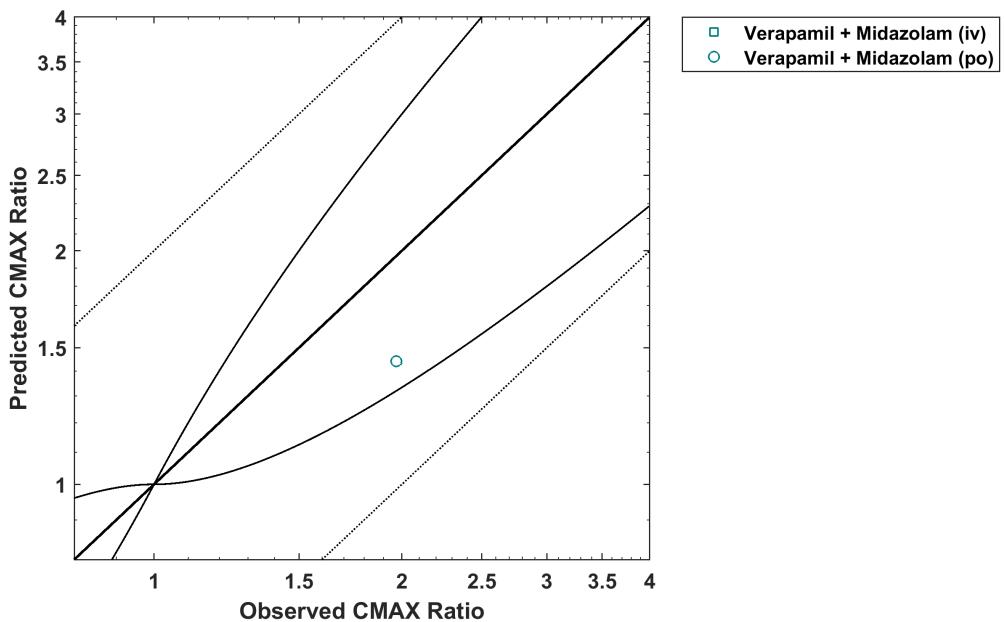
Verapamil



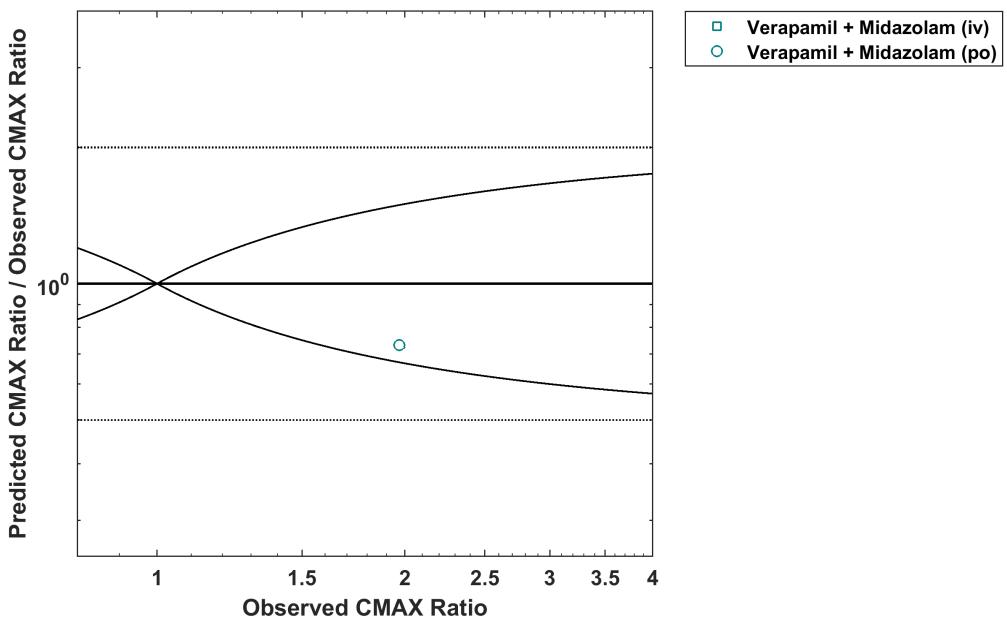
CYP3A4 DDI Verapamil



CYP3A4 DDI Verapamil



CYP3A4 DDI Verapamil



CYP3A4 DDI Verapamil

GMFE (AUC) = 1.479721

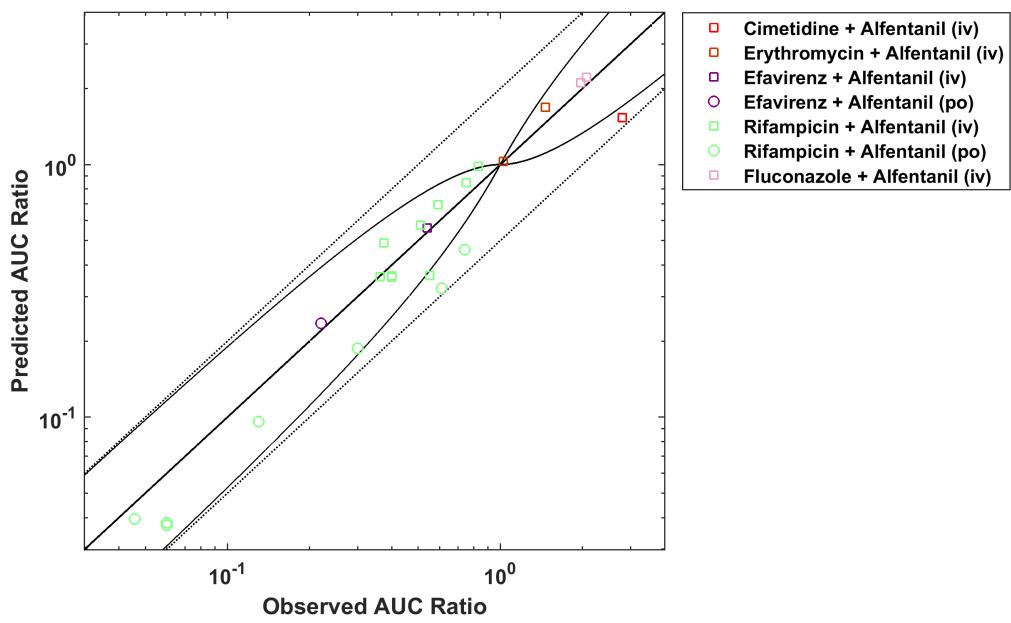
GMFE (CMAX) = 1.366377

AUC	Number	Ratio [%]
Points total	3	-
Points within Guest et al.	2	66.6667
Points within 2-fold	2	66.6667

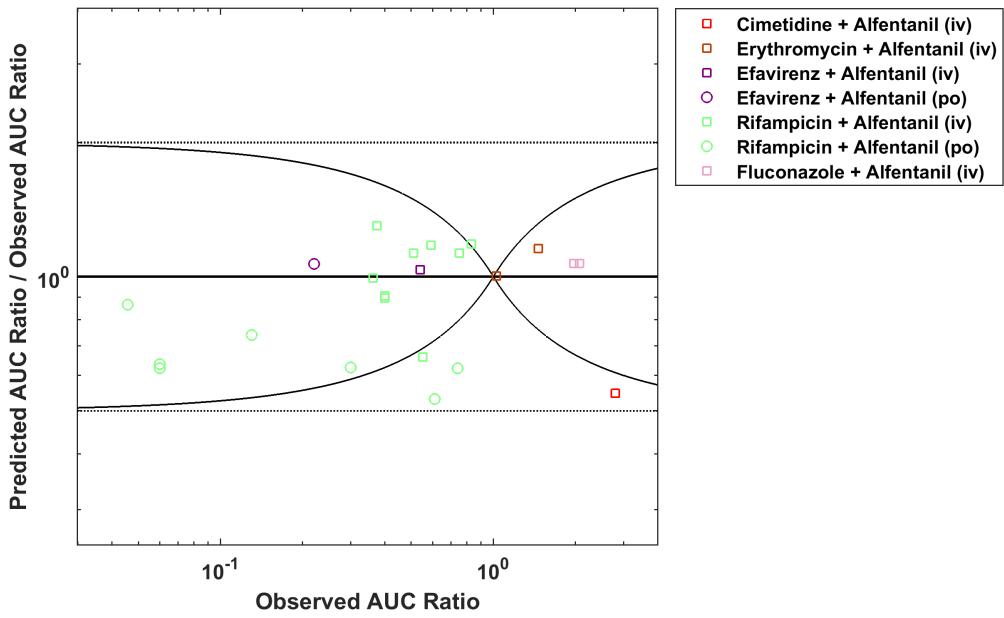
CMAX	Number	Ratio [%]
Points total	1	-
Points within Guest et al.	1	100
Points within 2-fold	1	100

Victim

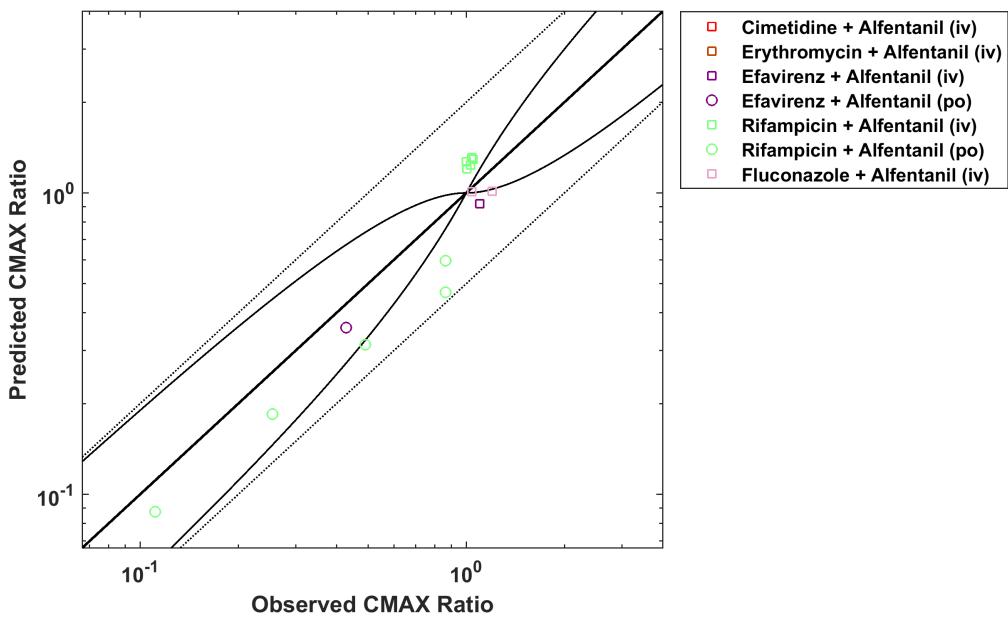
Alfentanil



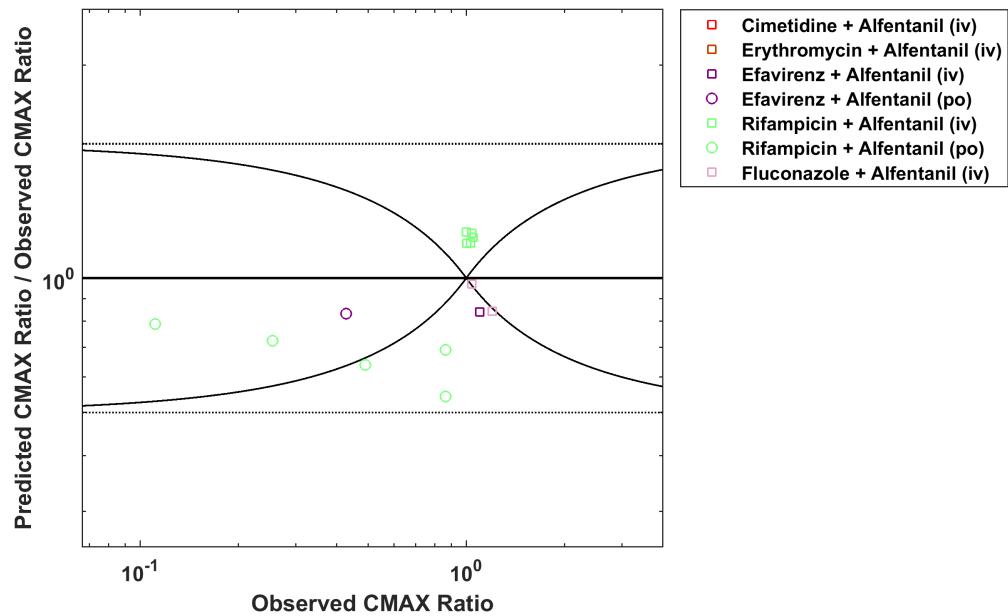
CYP3A4 DDI Alfentanil



CYP3A4 DDI Alfentanil



CYP3A4 DDI Alfentanil



CYP3A4 DDI Alfentanil

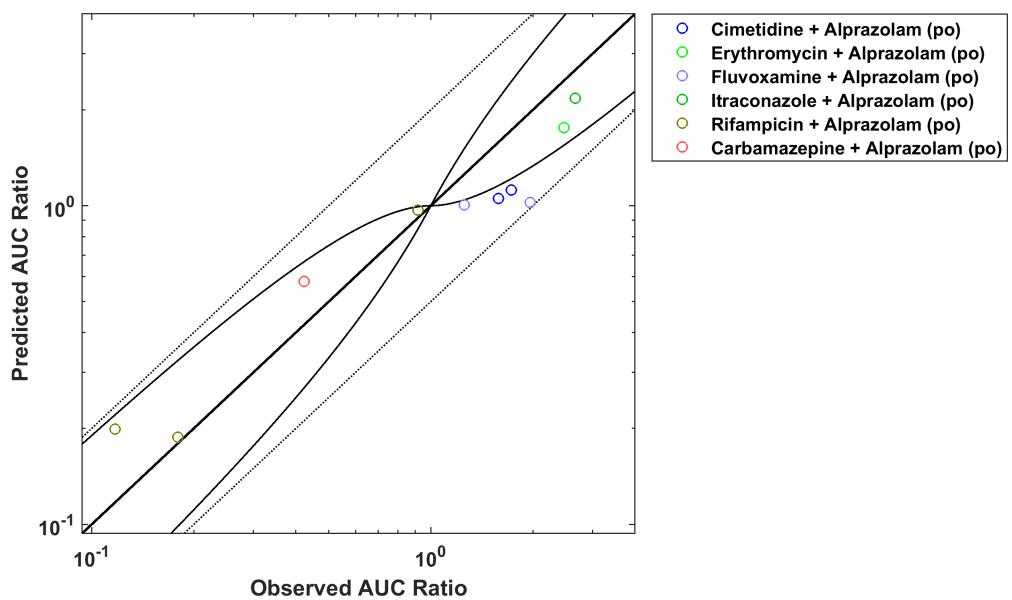
GMFE (AUC) = 1.265356

GMFE (CMAX) = 1.292221

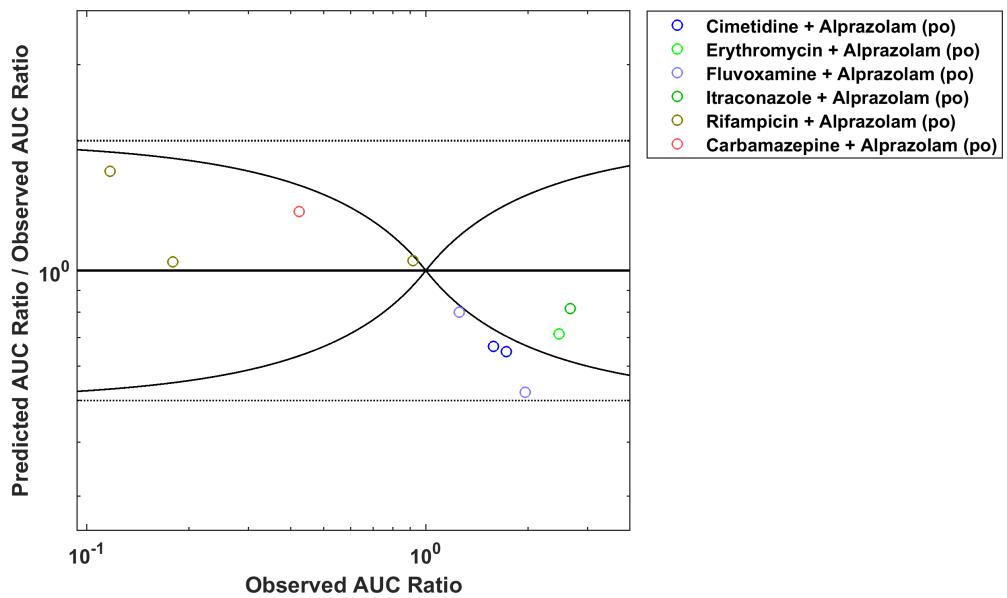
AUC	Number	Ratio [%]
Points total	23	-
Points within Guest et al.	18	78.2609
Points within 2-fold	23	100

CMAX	Number	Ratio [%]
Points total	14	-
Points within Guest et al.	4	28.5714
Points within 2-fold	14	100

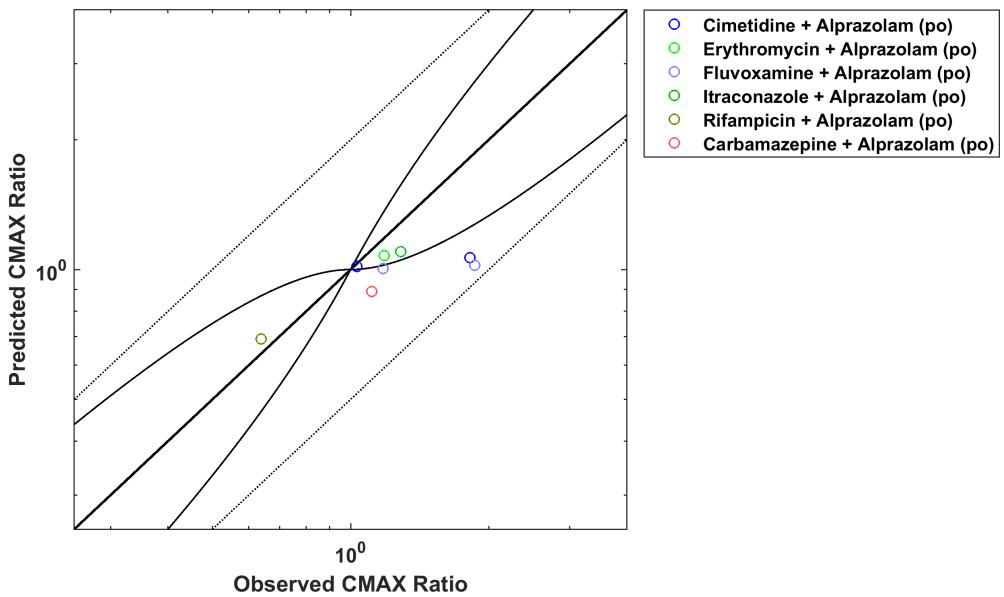
Alprazolam



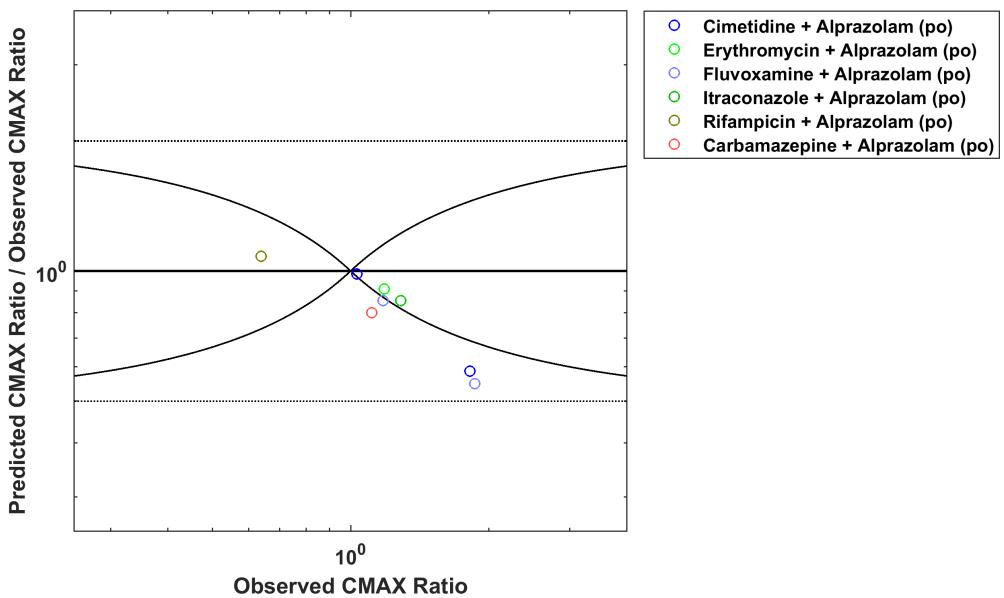
CYP3A4 DDI Alprazolam



CYP3A4 DDI Alprazolam



CYP3A4 DDI Alprazolam



CYP3A4 DDI Alprazolam

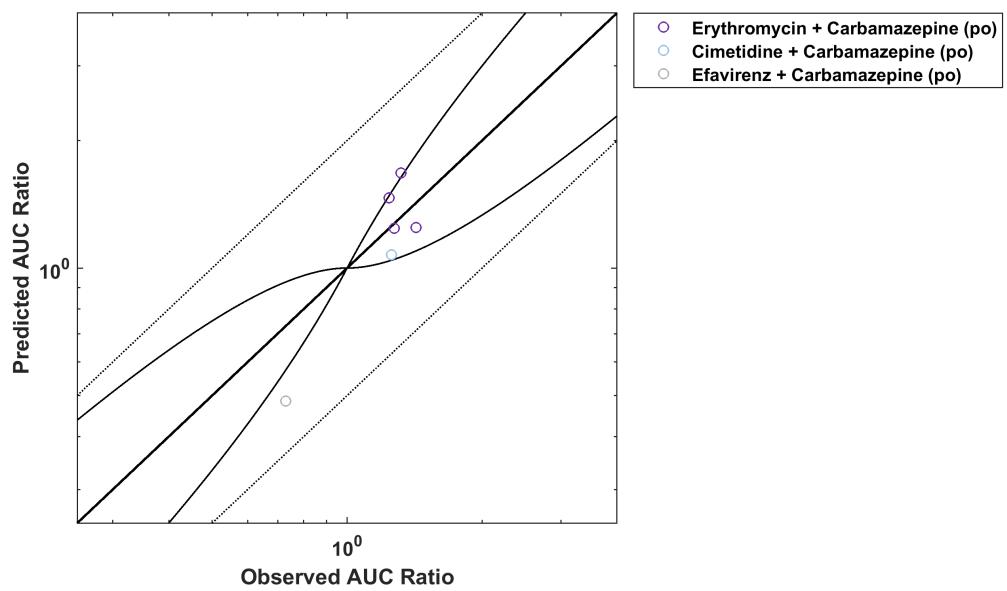
GMFE (AUC) = 1.376874

GMFE (CMAX) = 1.261609

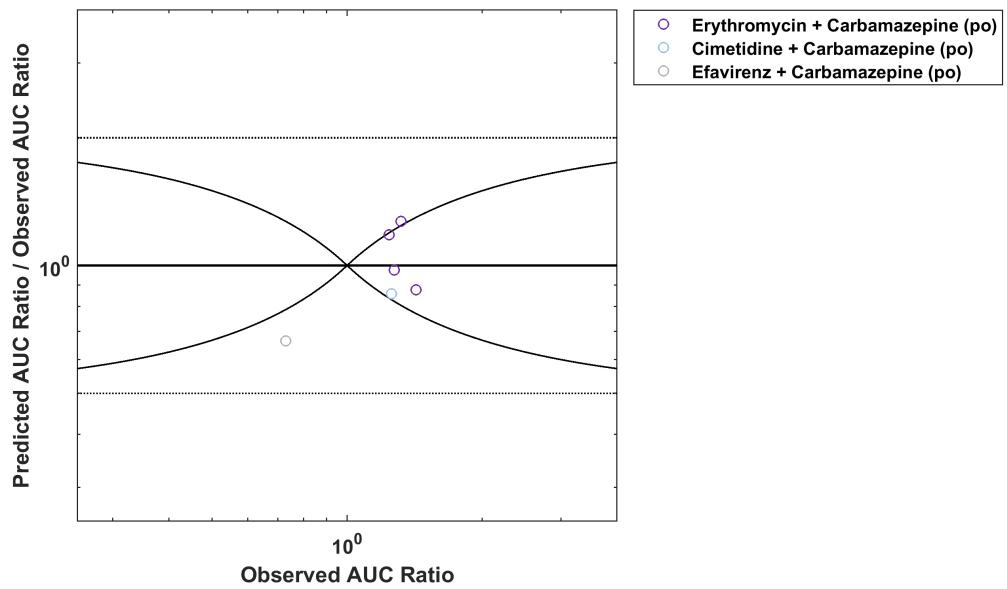
	AUC	Number	Ratio [%]
Points total		10	-
Points within Guest et al.		6	60
Points within 2-fold		10	100

	CMAX	Number	Ratio [%]
Points total		8	-
Points within Guest et al.		4	50
Points within 2-fold		8	100

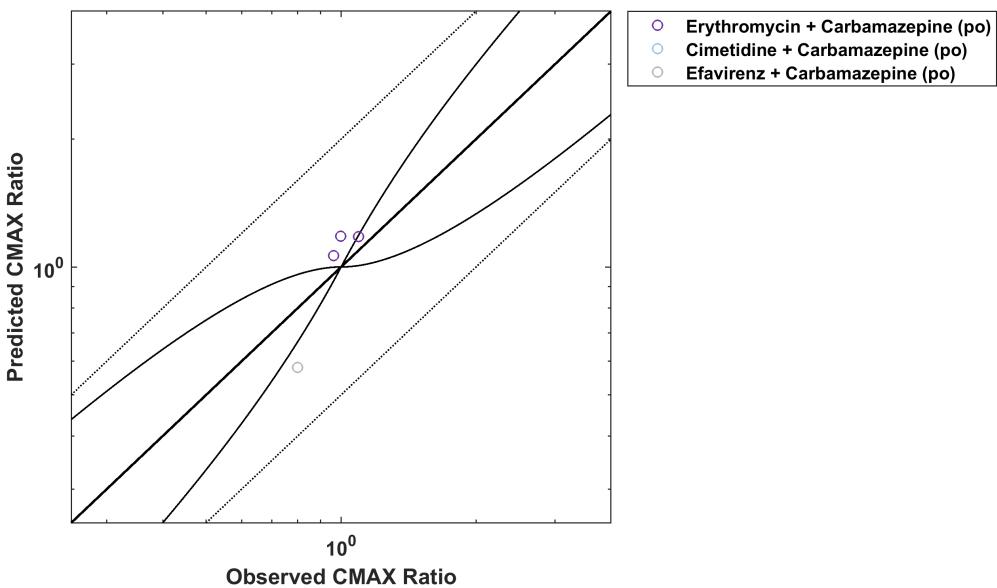
Carbamazepine



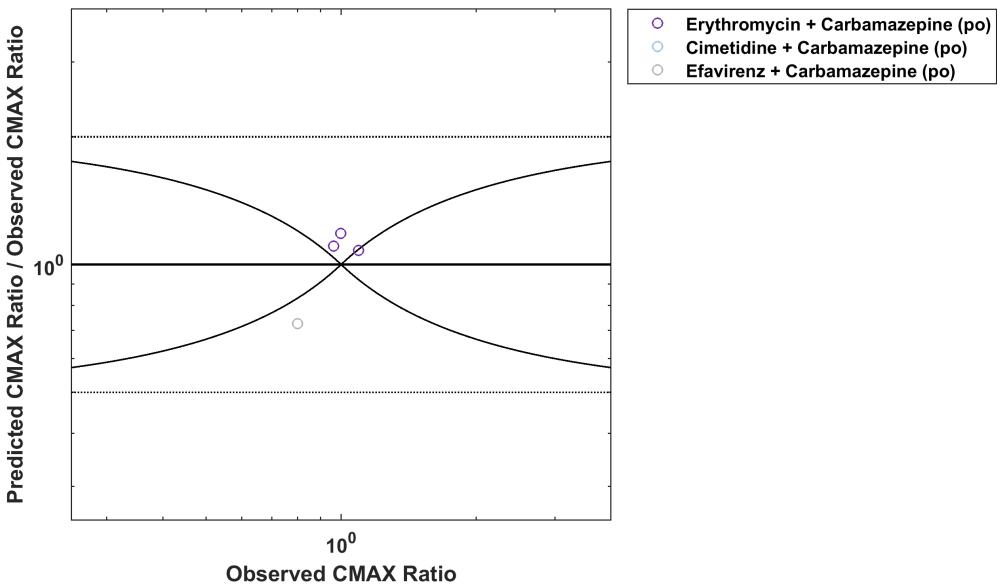
CYP3A4 DDI Carbamazepine



CYP3A4 DDI Carbamazepine



CYP3A4 DDI Carbamazepine



CYP3A4 DDI Carbamazepine

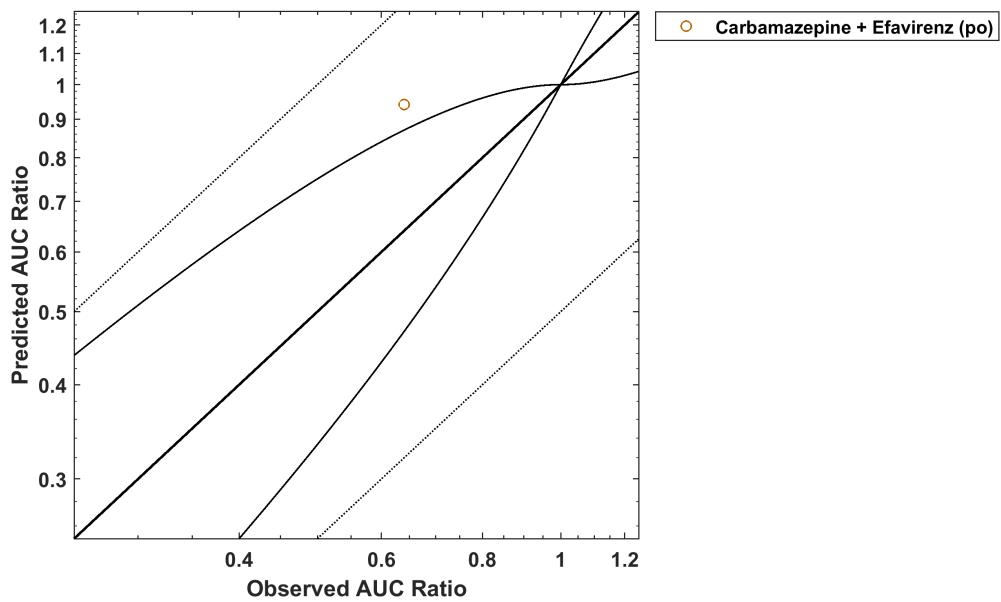
GMFE (AUC) = 1.206031

GMFE (CMAX) = 1.180932

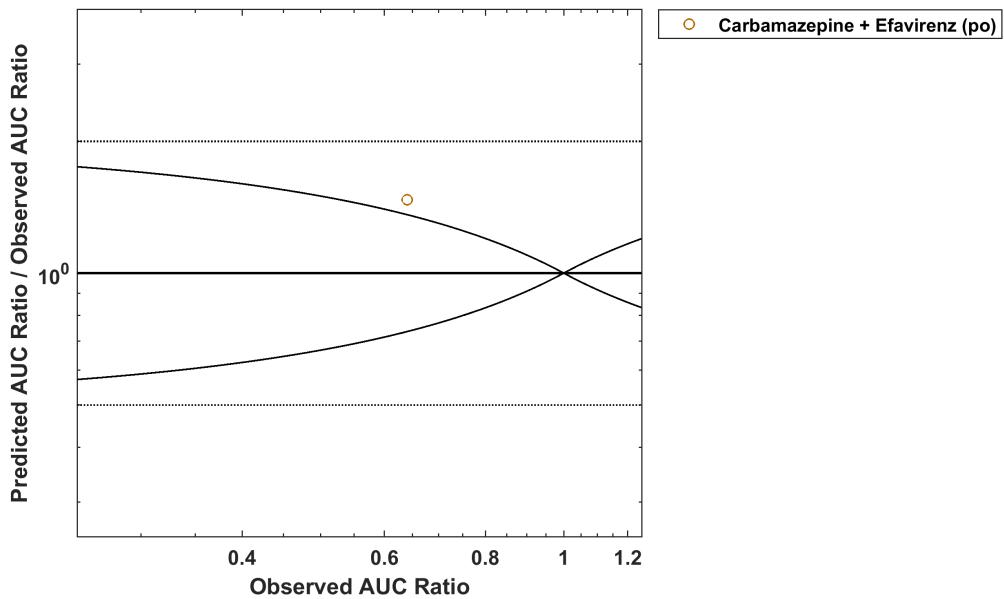
	AUC	Number	Ratio [%]
Points total	6	-	
Points within Guest et al.	4	66.6667	
Points within 2-fold	6	100	

	CMAX	Number	Ratio [%]
Points total	4	-	
Points within Guest et al.	1	25	
Points within 2-fold	4	100	

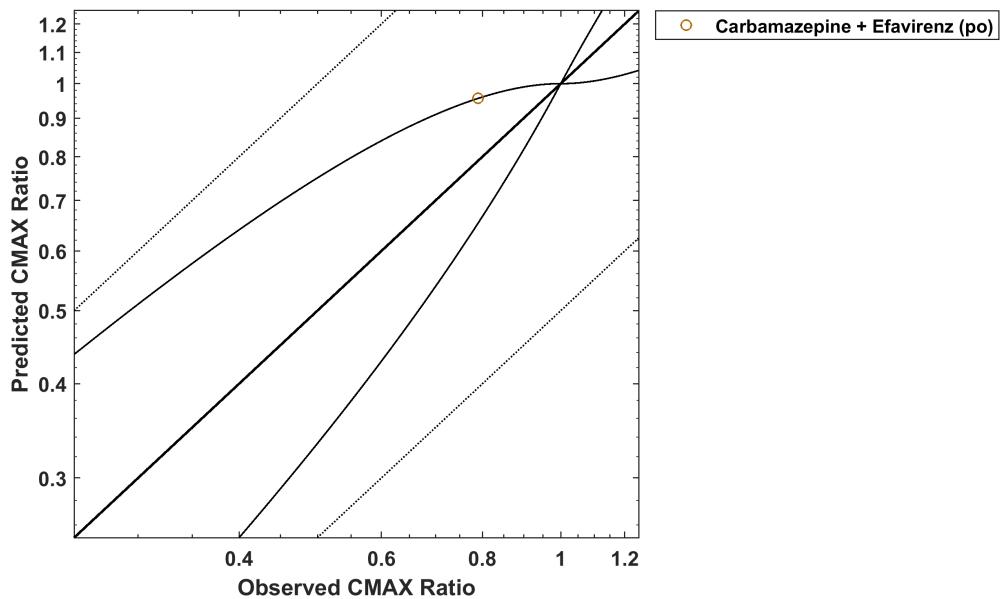
Efavirenz



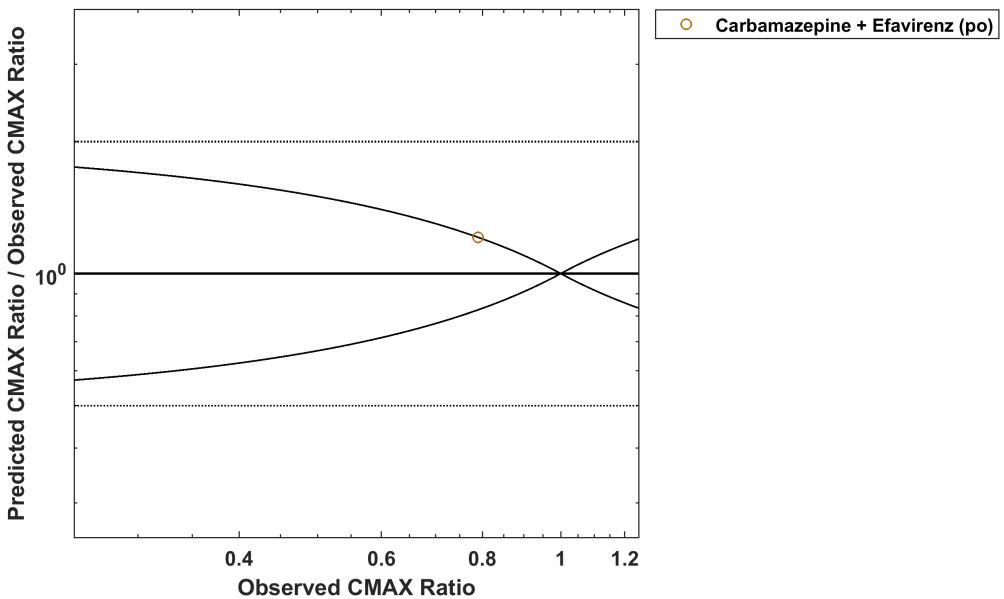
CYP3A4 DDI Efavirenz



CYP3A4 DDI Efavirenz



CYP3A4 DDI Efavirenz



CYP3A4 DDI Efavirenz

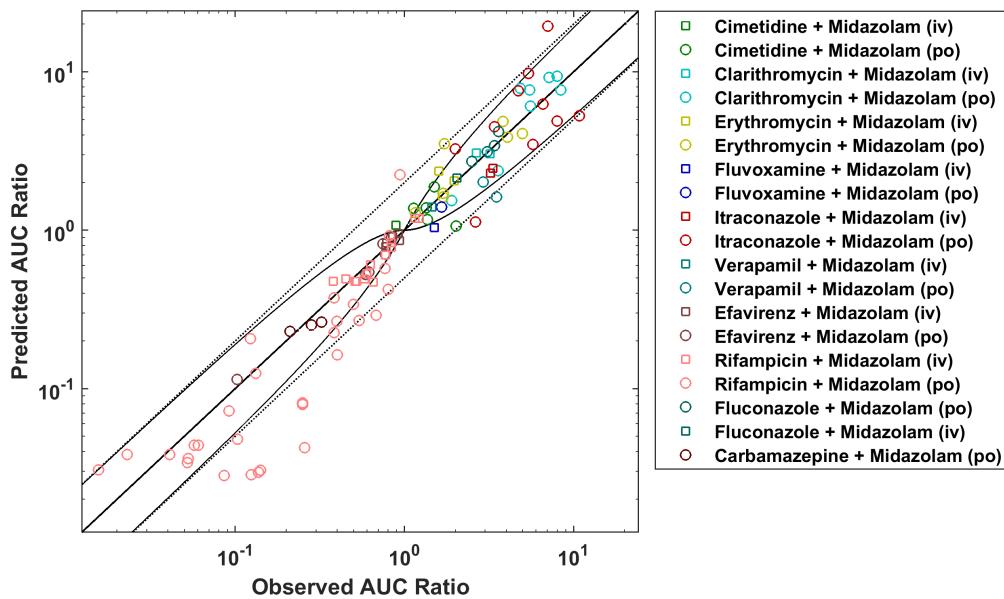
GMFE (AUC) = 1.471139

GMFE (CMAX) = 1.210228

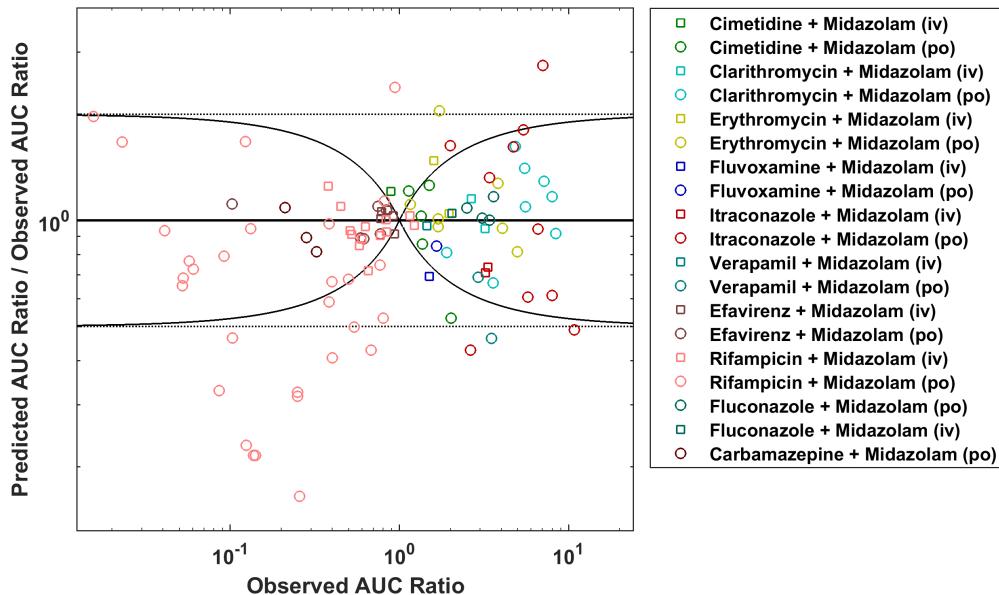
AUC	Number	Ratio [%]
Points total	1	-
Points within Guest et al.	0	0
Points within 2-fold	1	100

CMAX	Number	Ratio [%]
Points total	1	-
Points within Guest et al.	0	0
Points within 2-fold	1	100

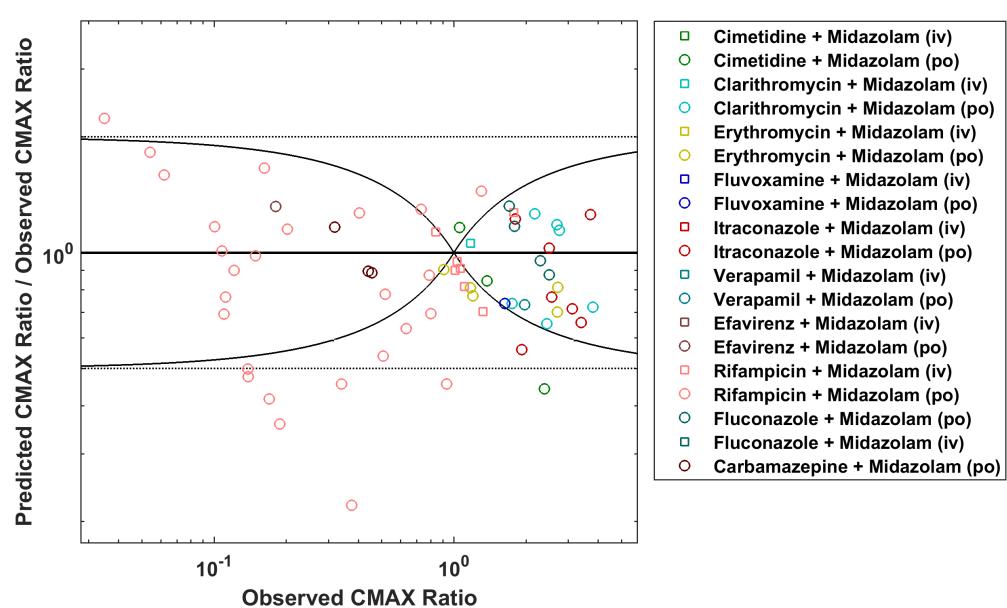
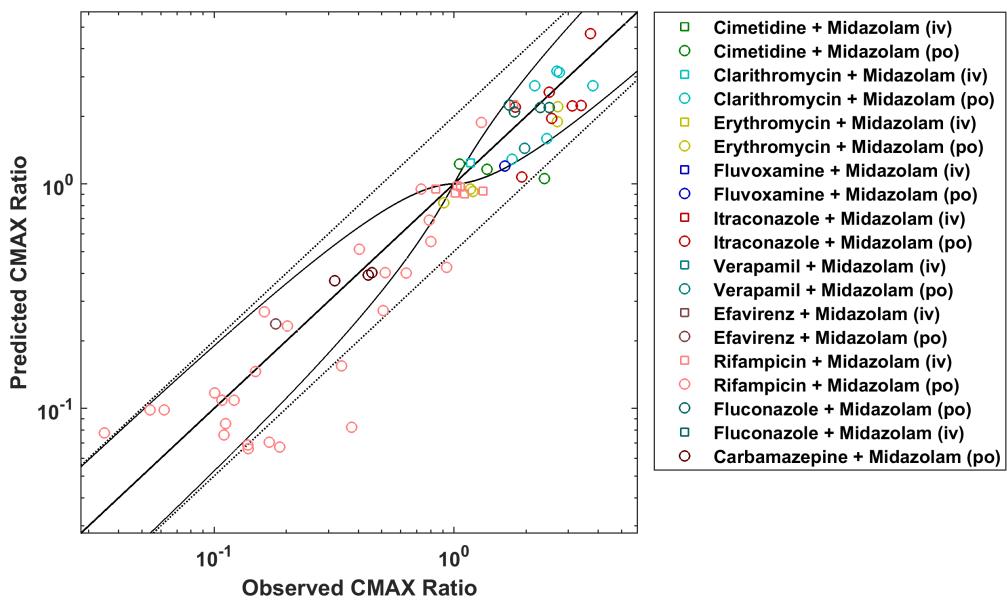
Midazolam



CYP3A4 DDI Midazolam



CYP3A4 DDI Midazolam



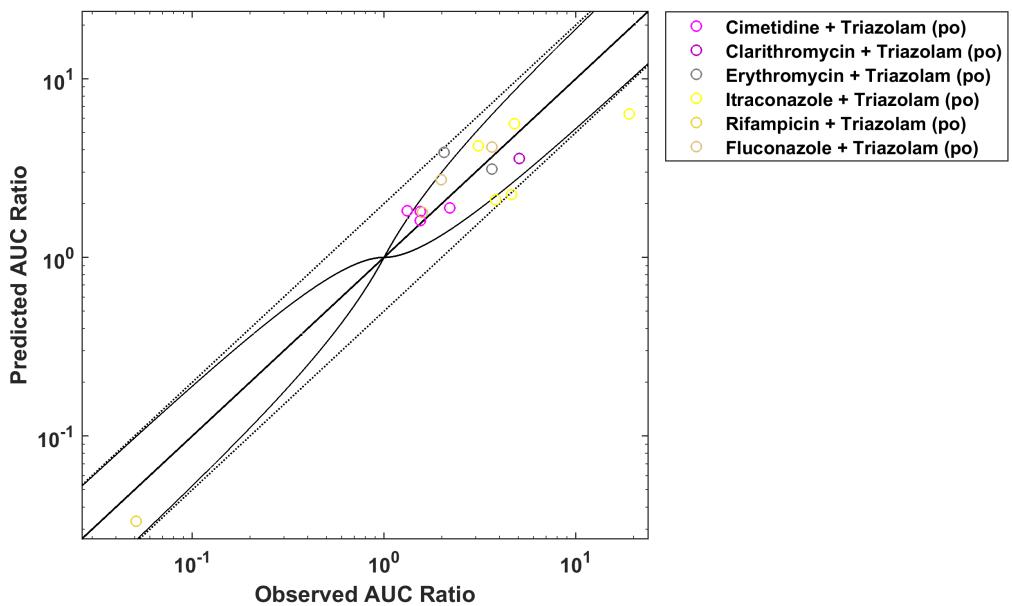
GMFE (AUC) = 1.411839

GMFE (CMAX) = 1.394057

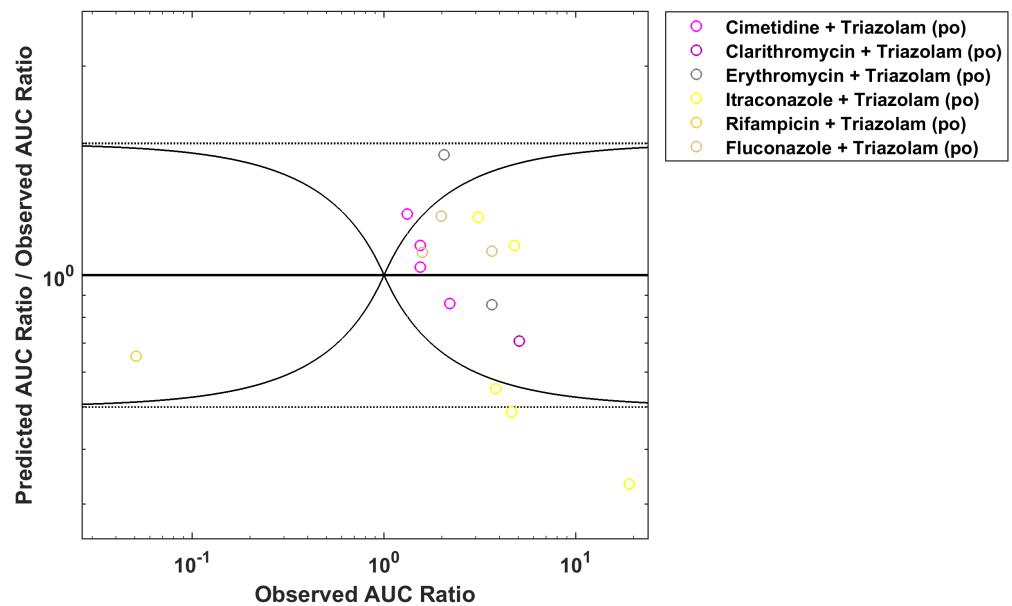
	AUC	Number	Ratio [%]
Points total		104	-
Points within Guest et al.		76	73.0769
Points within 2-fold		87	83.6538

	CMAX	Number	Ratio [%]
Points total		65	-
Points within Guest et al.		41	63.0769
Points within 2-fold		56	86.1538

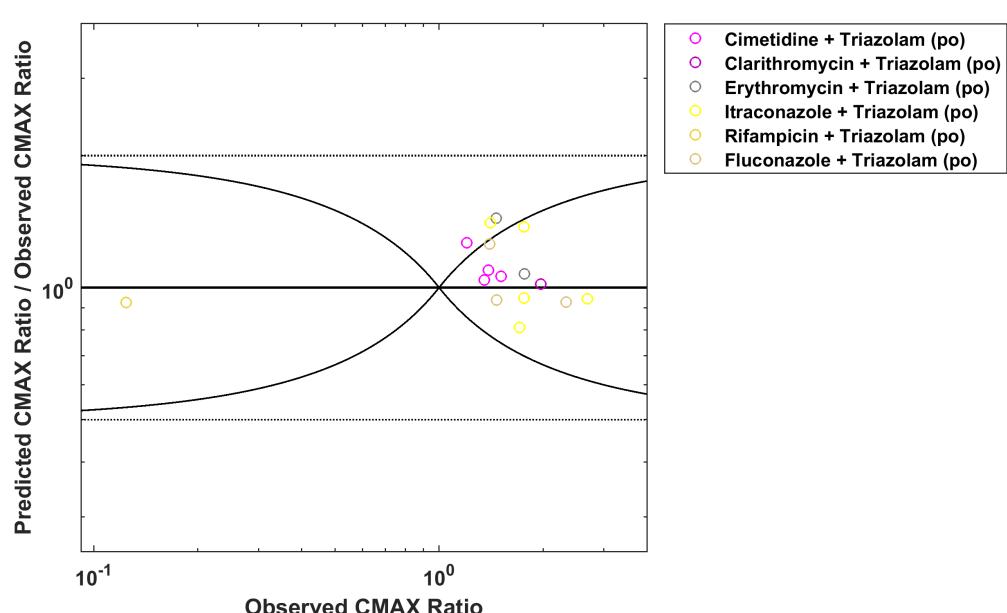
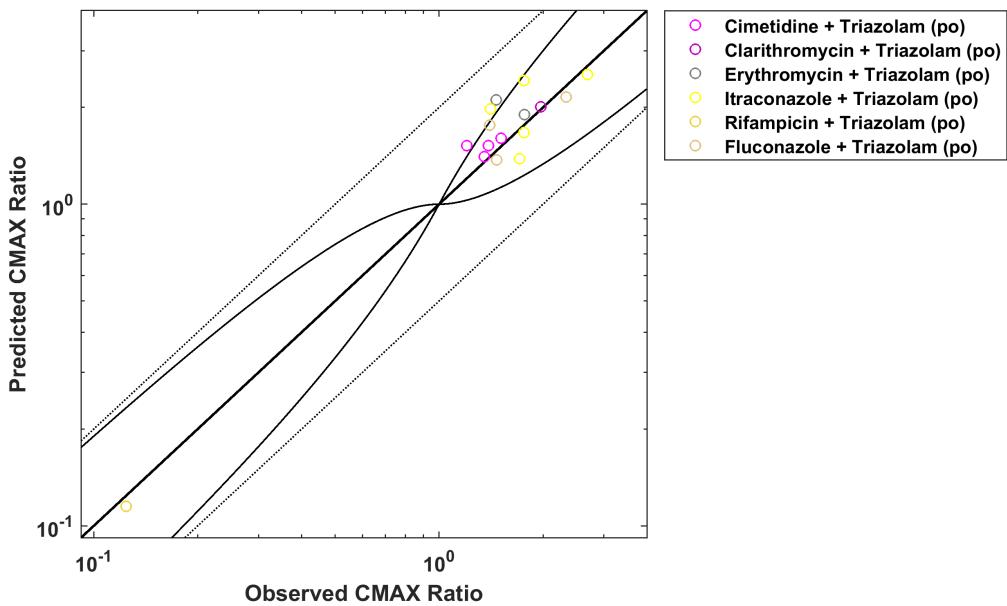
Triazolam



CYP3A4 DDI Triazolam



CYP3A4 DDI Triazolam



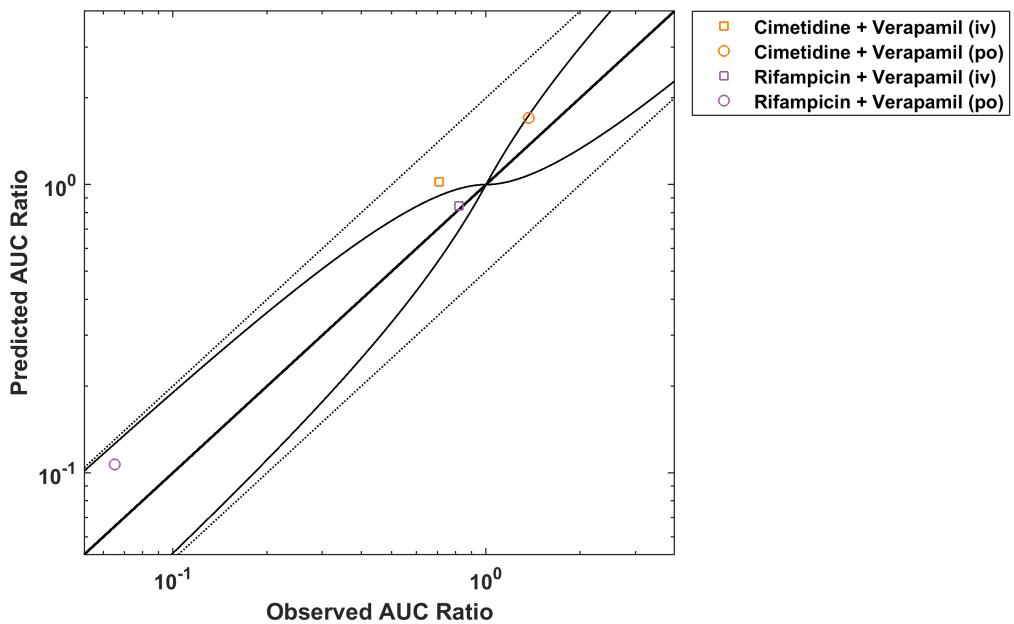
GMFE (AUC) = 1.424748

GMFE (CMAX) = 1.155567

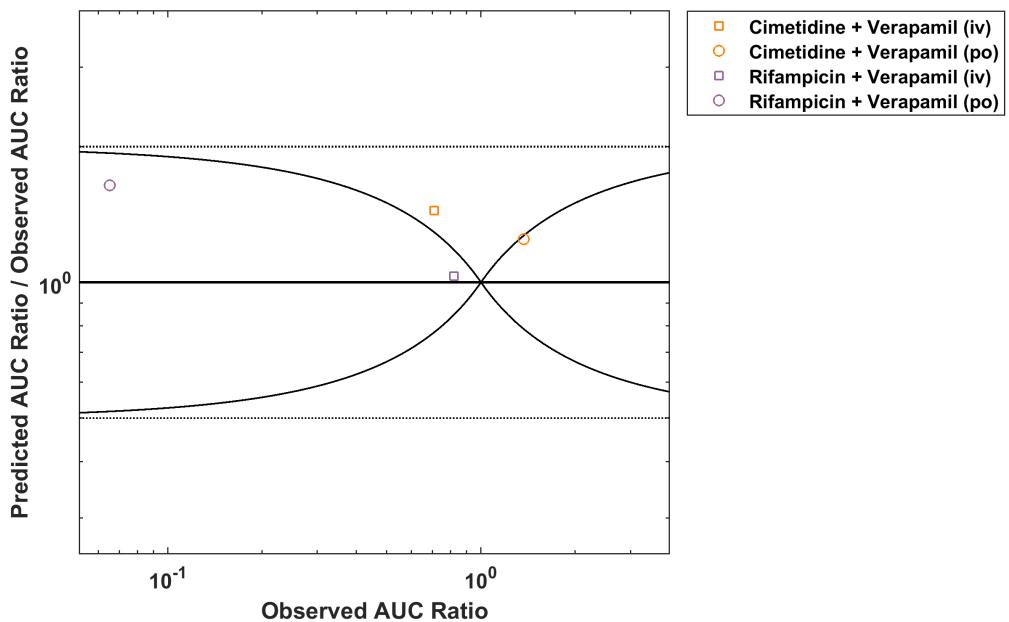
AUC	Number	Ratio [%]
Points total	16	-
Points within Guest et al.	11	68.75
Points within 2-fold	14	87.5

CMAX	Number	Ratio [%]
Points total	16	-
Points within Guest et al.	13	81.25
Points within 2-fold	16	100

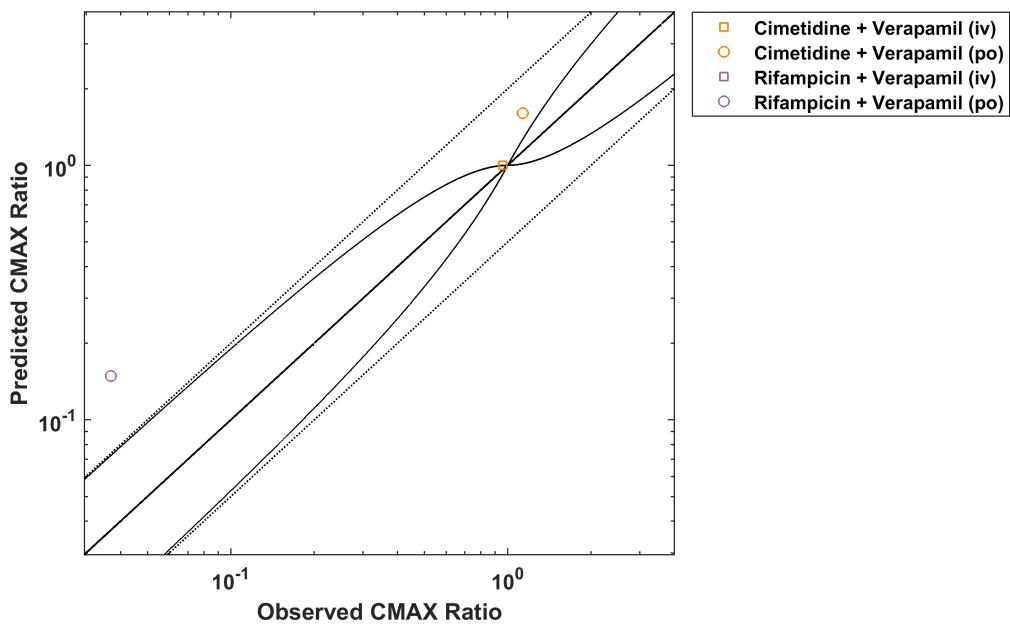
Verapamil



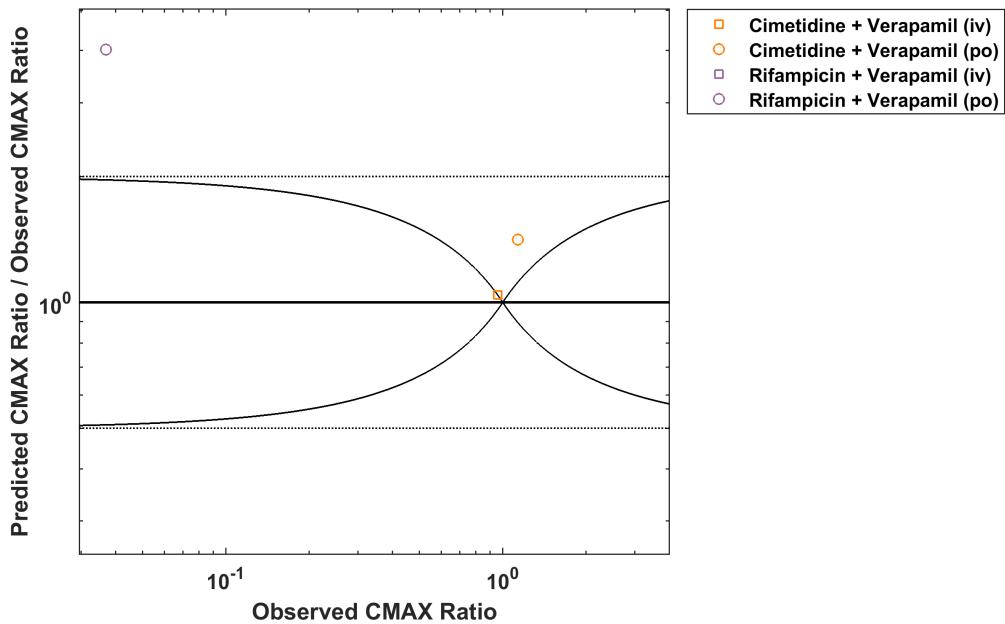
CYP3A4 DDI Verapamil



CYP3A4 DDI Verapamil



CYP3A4 DDI Verapamil



CYP3A4 DDI Verapamil

GMFE (AUC) = 1.320781

GMFE (CMAX) = 1.808710

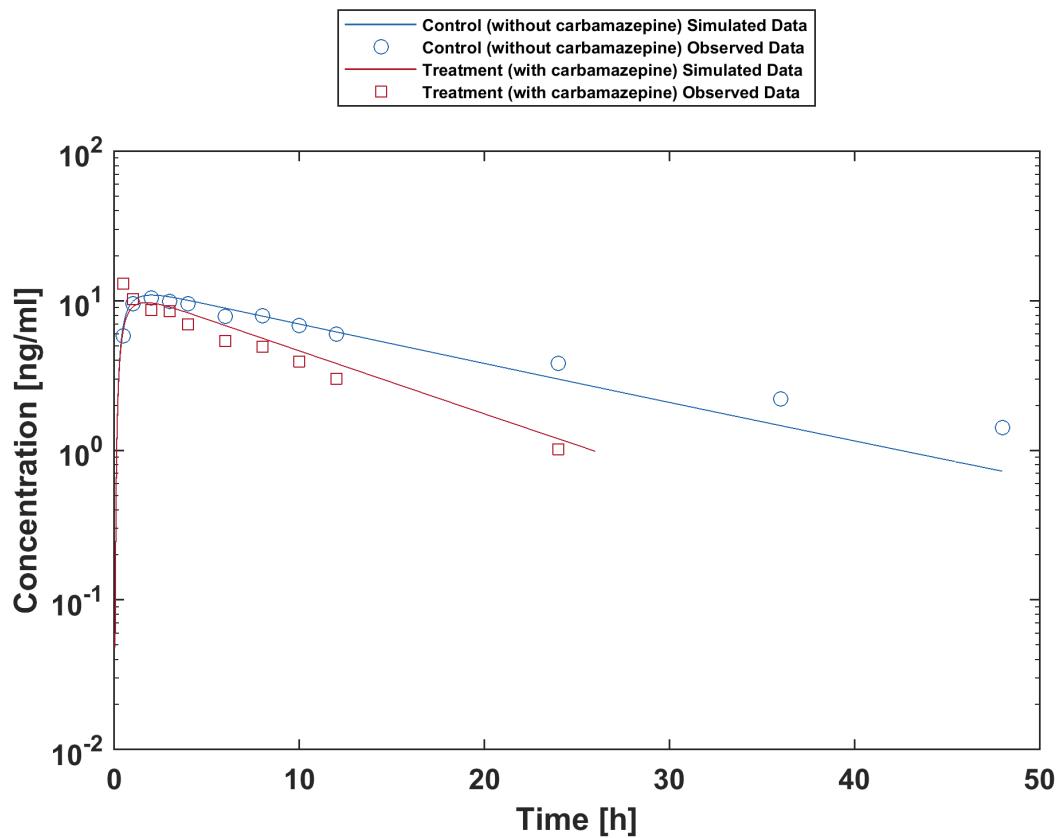
	AUC	Number	Ratio [%]
Points total		4	-
Points within Guest et al.		3	75
Points within 2-fold		4	100

	CMAX	Number	Ratio [%]
Points total		3	-
Points within Guest et al.		0	0
Points within 2-fold		2	66.6667

3 Concentration-Time Profiles

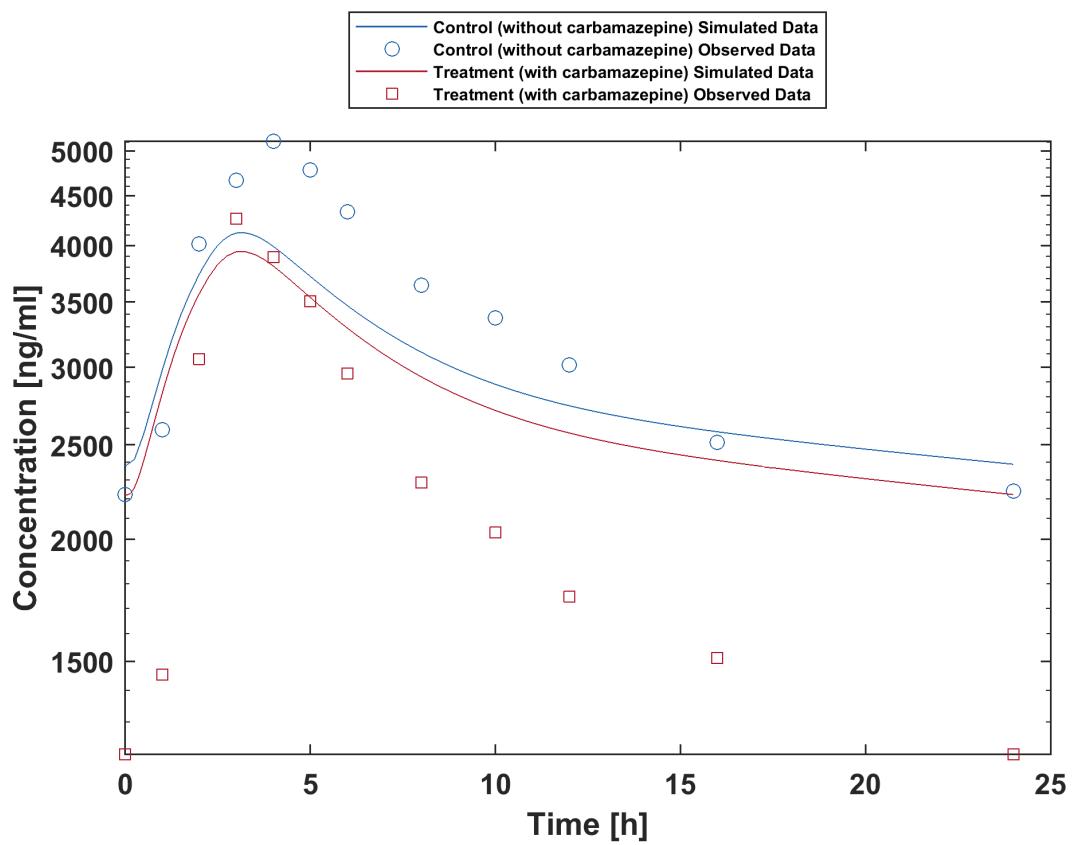
The following section shows concentration time profiles of the victim drugs of the simulated DDI studies in comparison to observed data (if available).

3.1 Carbamazepine - Alprazolam DDI



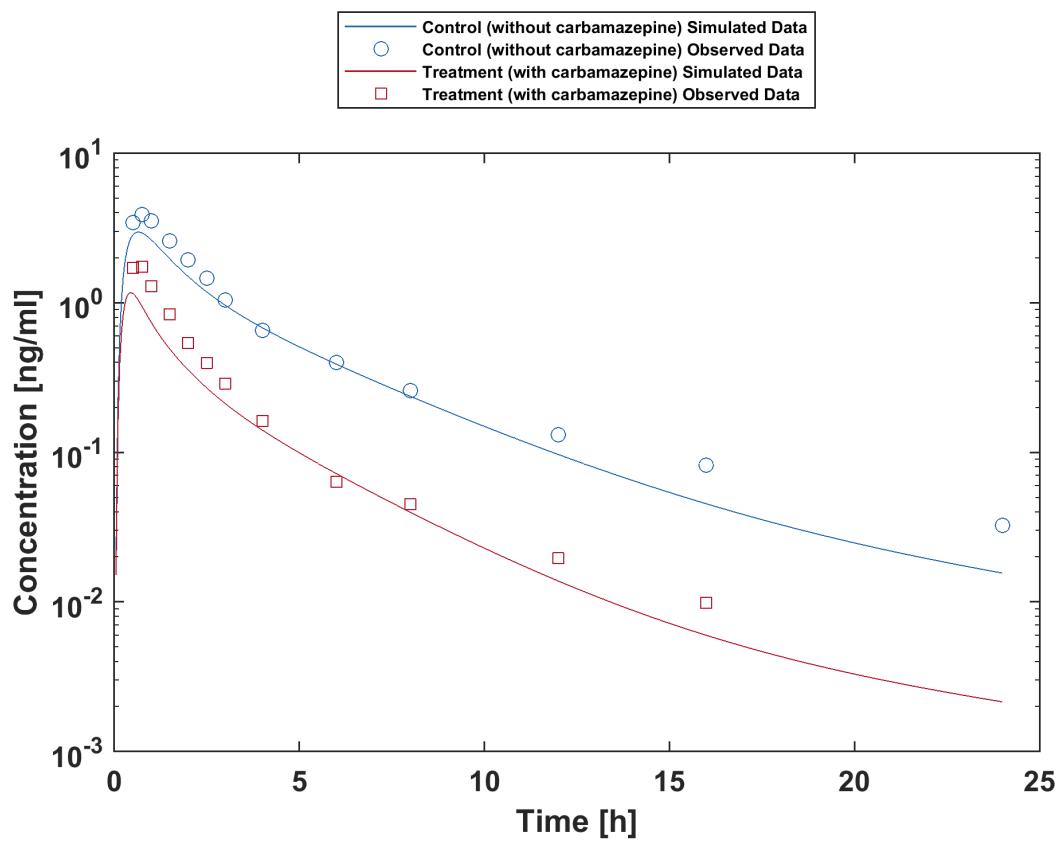
Furukori 1998

3.2 Carbamazepine - Efavirenz DDI

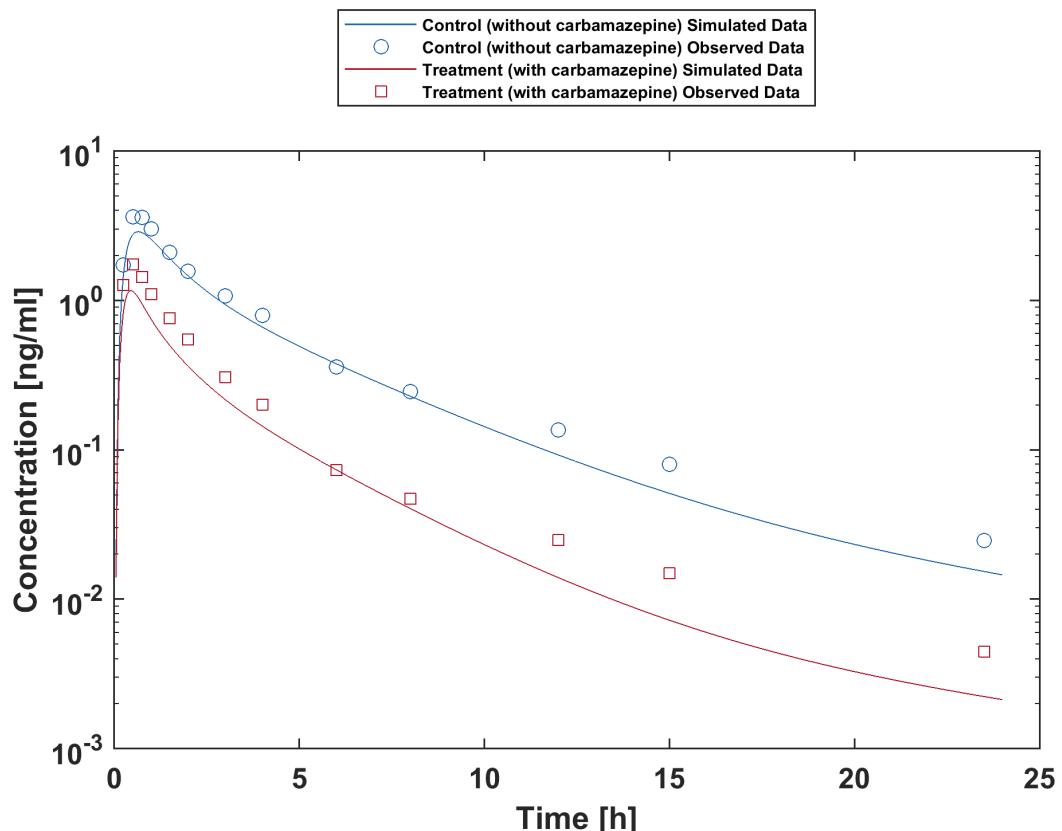


Ji 2008 (Arm 1, Perpetrator: Carbamazepine, Victim: Efavirenz)

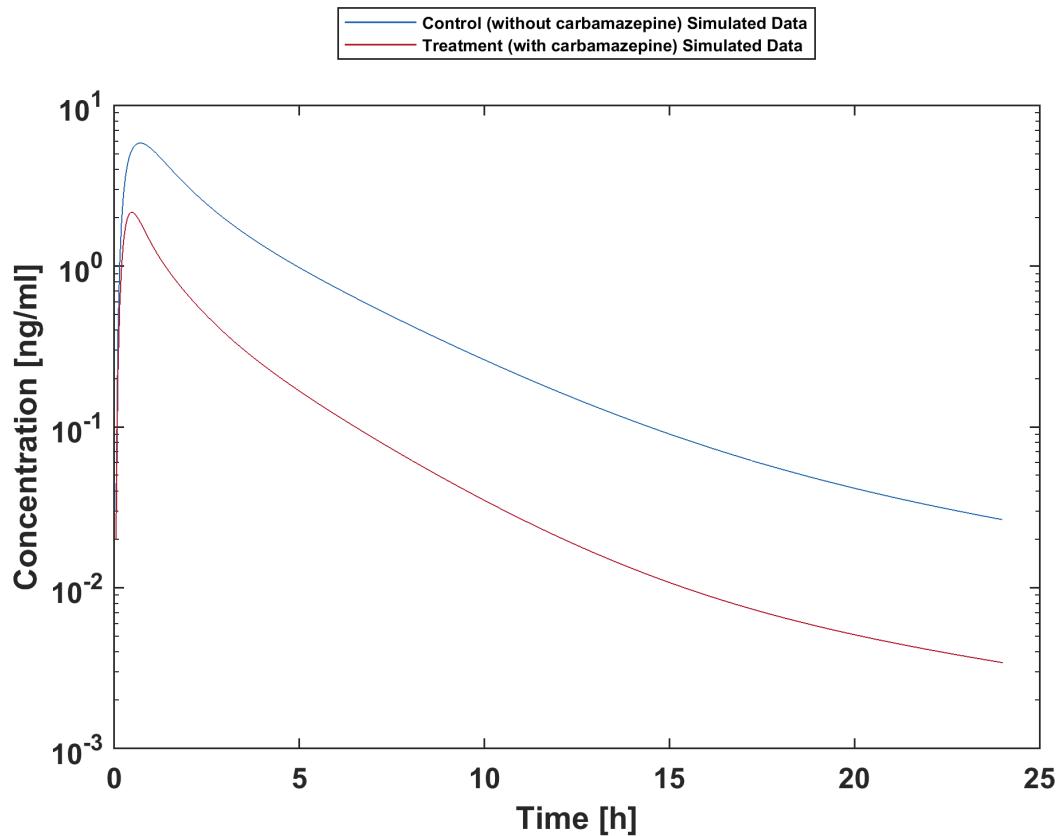
3.3 Carbamazepine - Midazolam DDI



Kanefendt 2023 (Study 1)

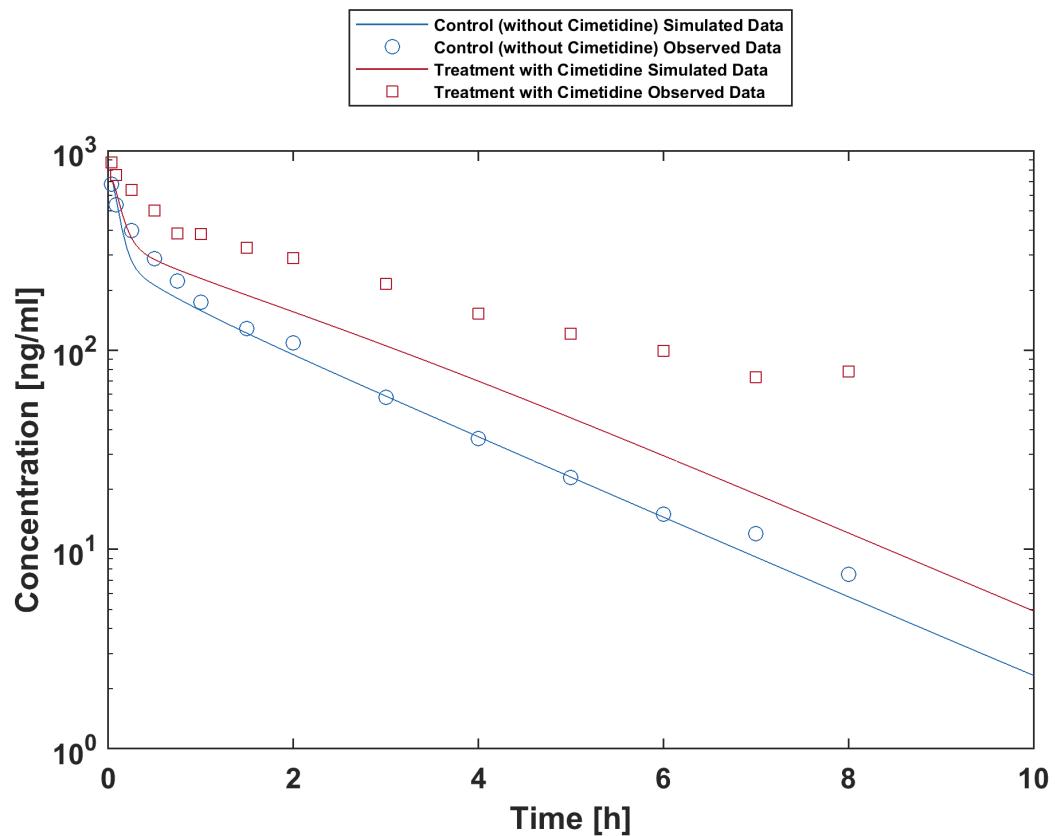


Kanefendt 2023 (Study 2)



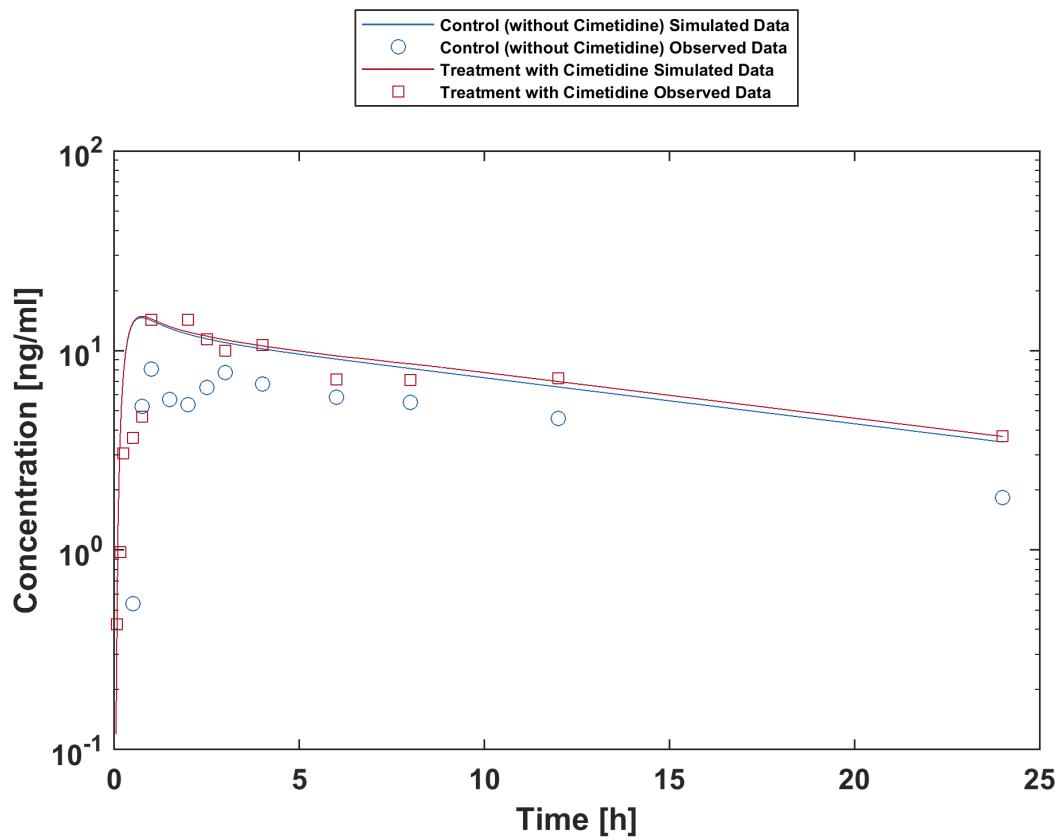
Lutz 2018

3.4 Cimetidine - Alfentanil DDI

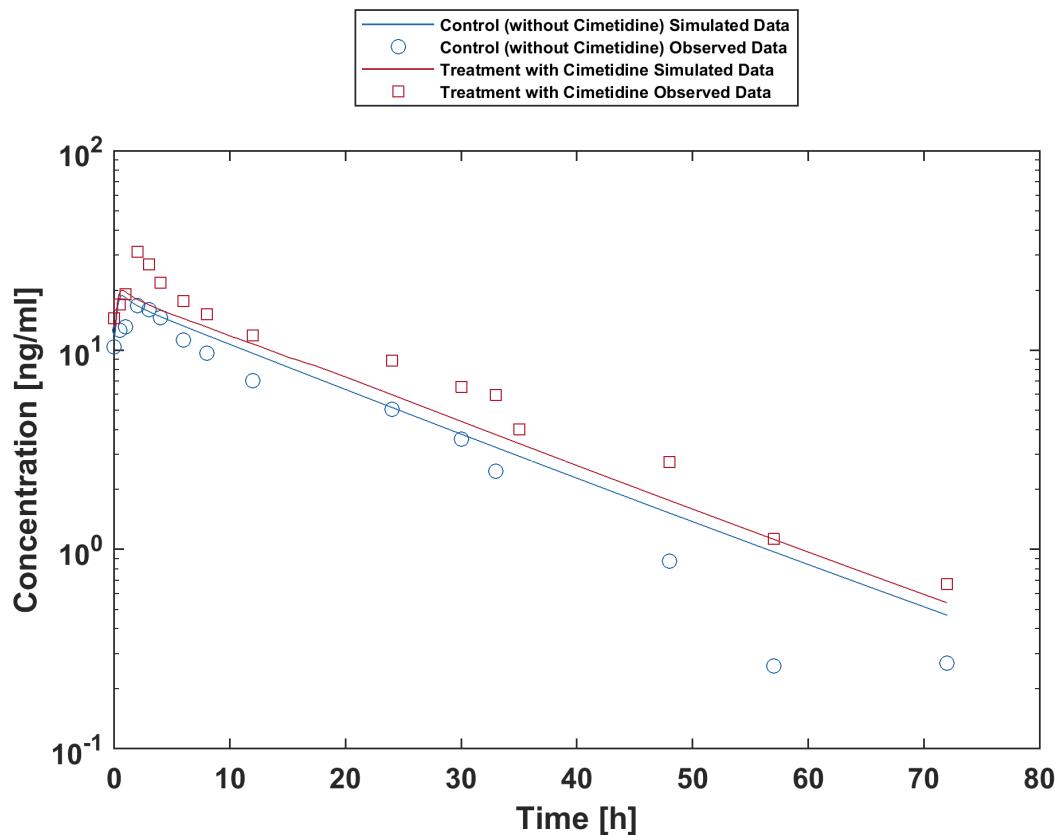


Kienlen 1993

3.5 Cimetidine - Alprazolam DDI

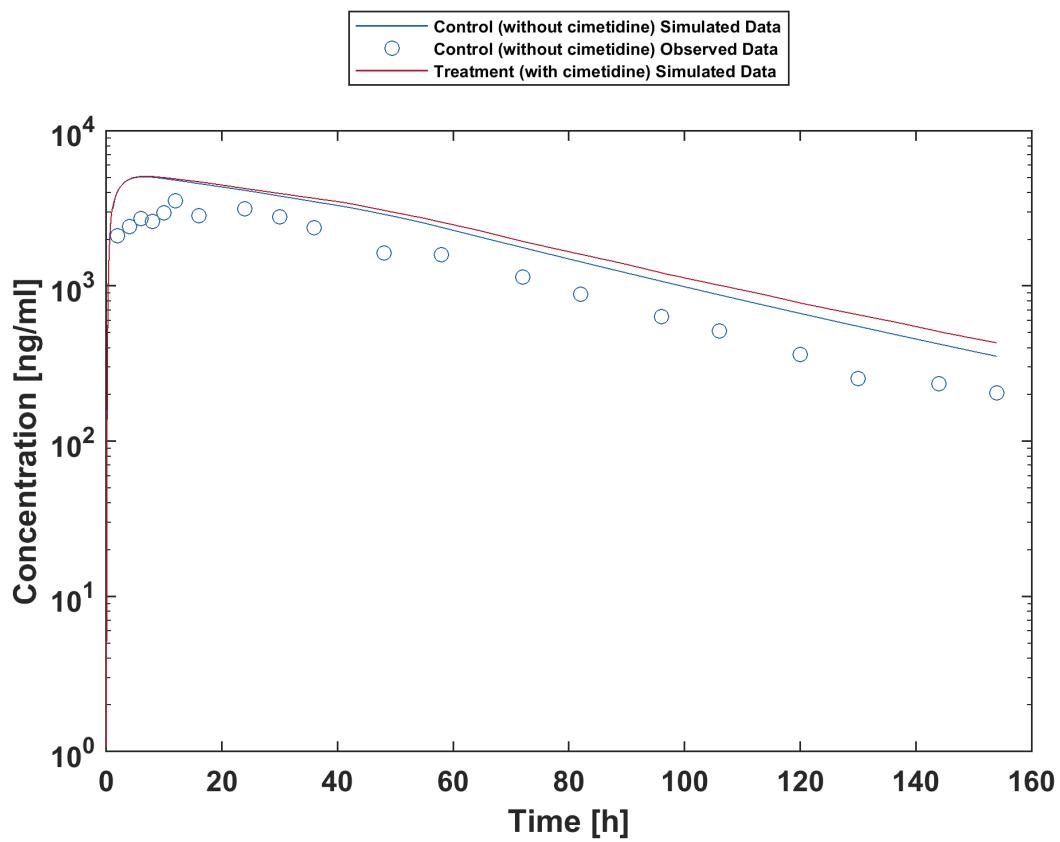


Abernethy 1983



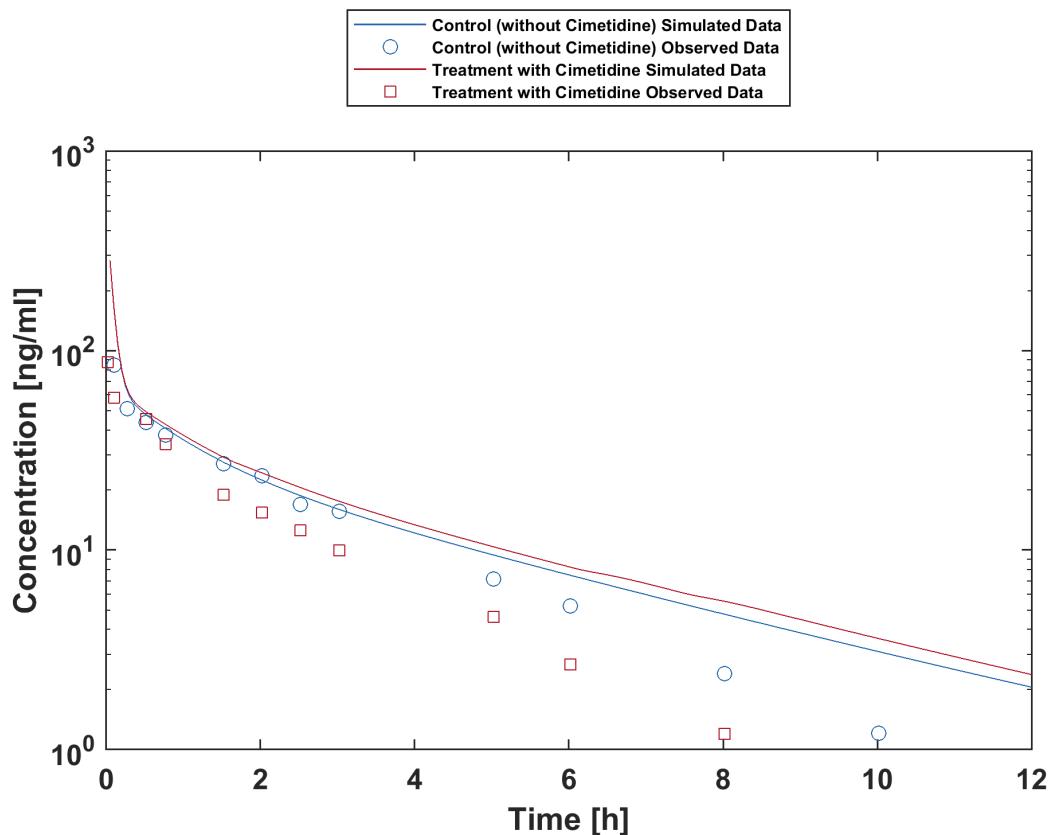
Pourbaix 1985

3.6 Cimetidine - Carbamazepine DDI

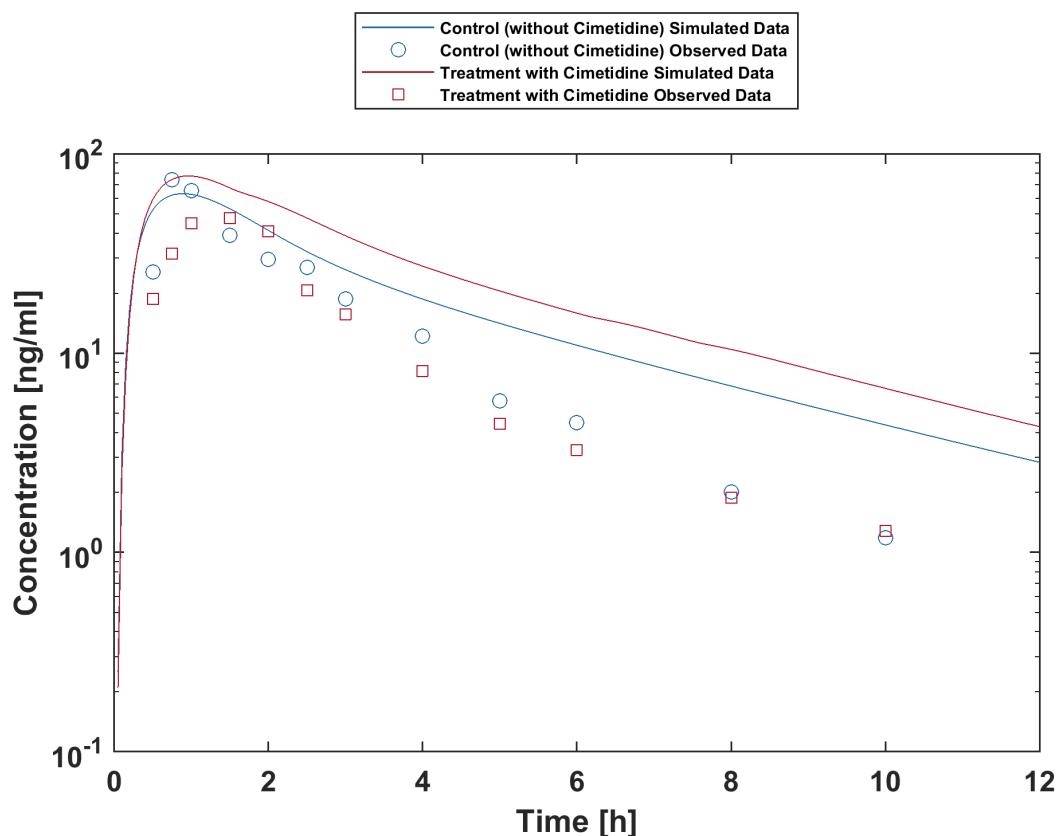


Dalton 1985a

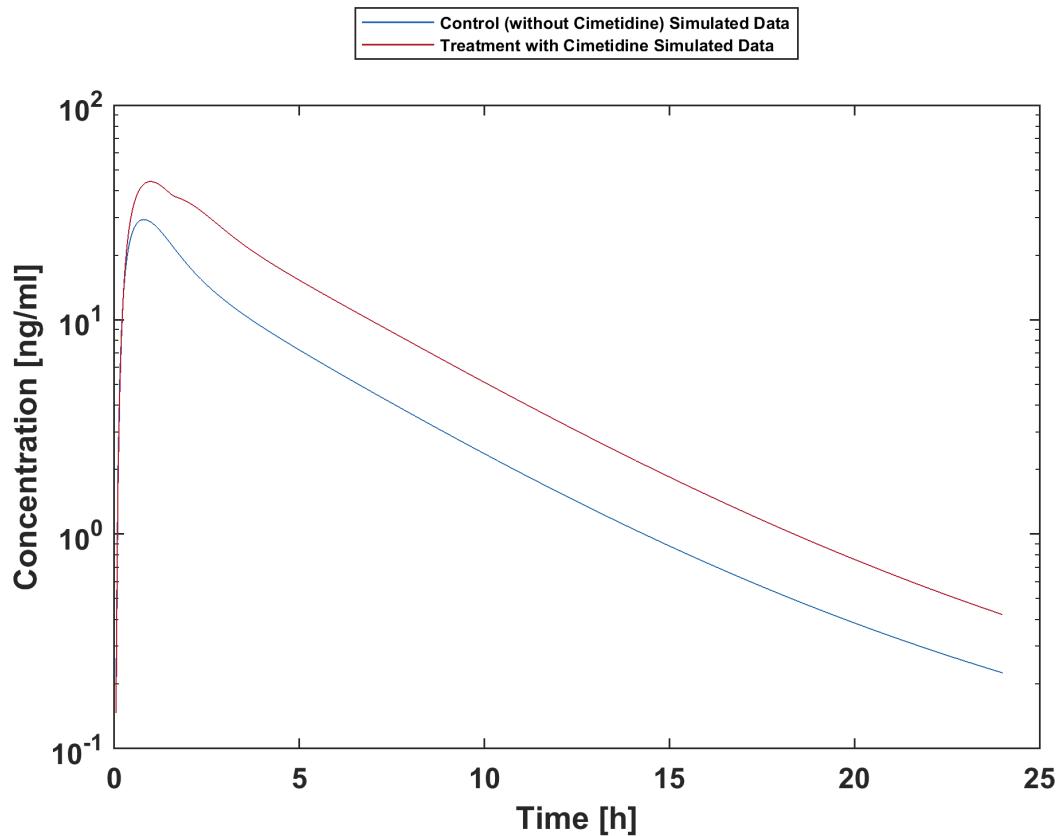
3.7 Cimetidine - Midazolam DDI



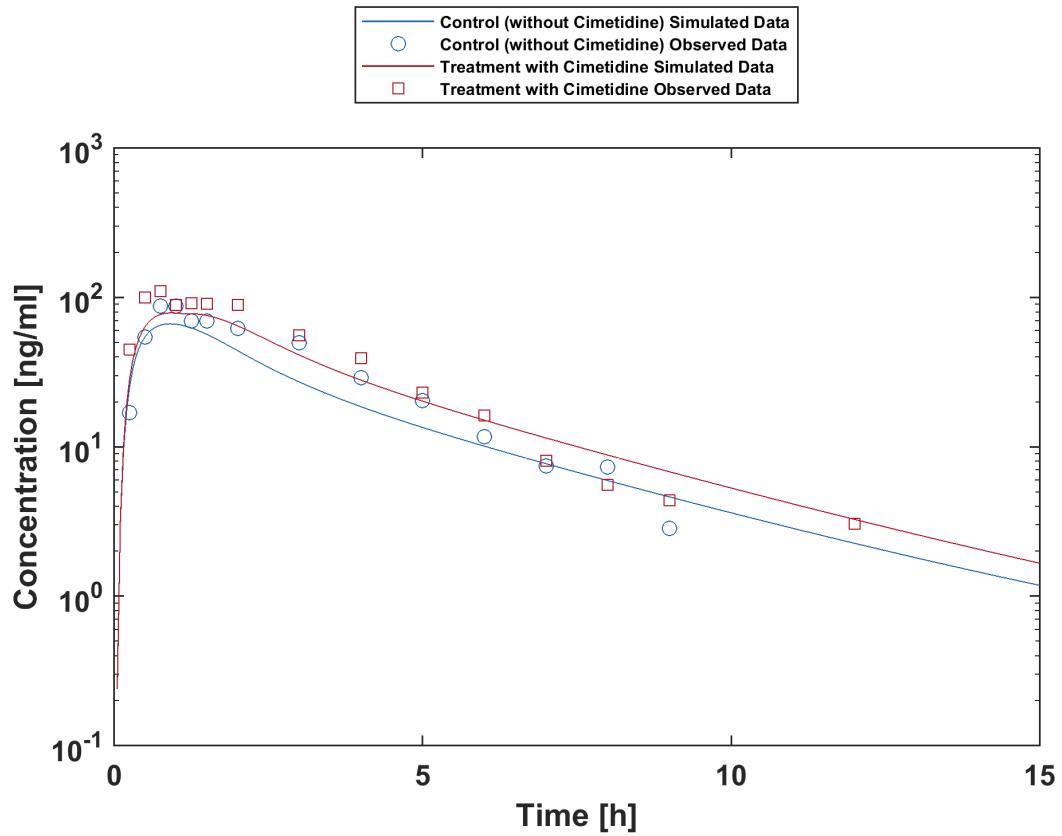
Greenblatt 1986 (midazolam IV)



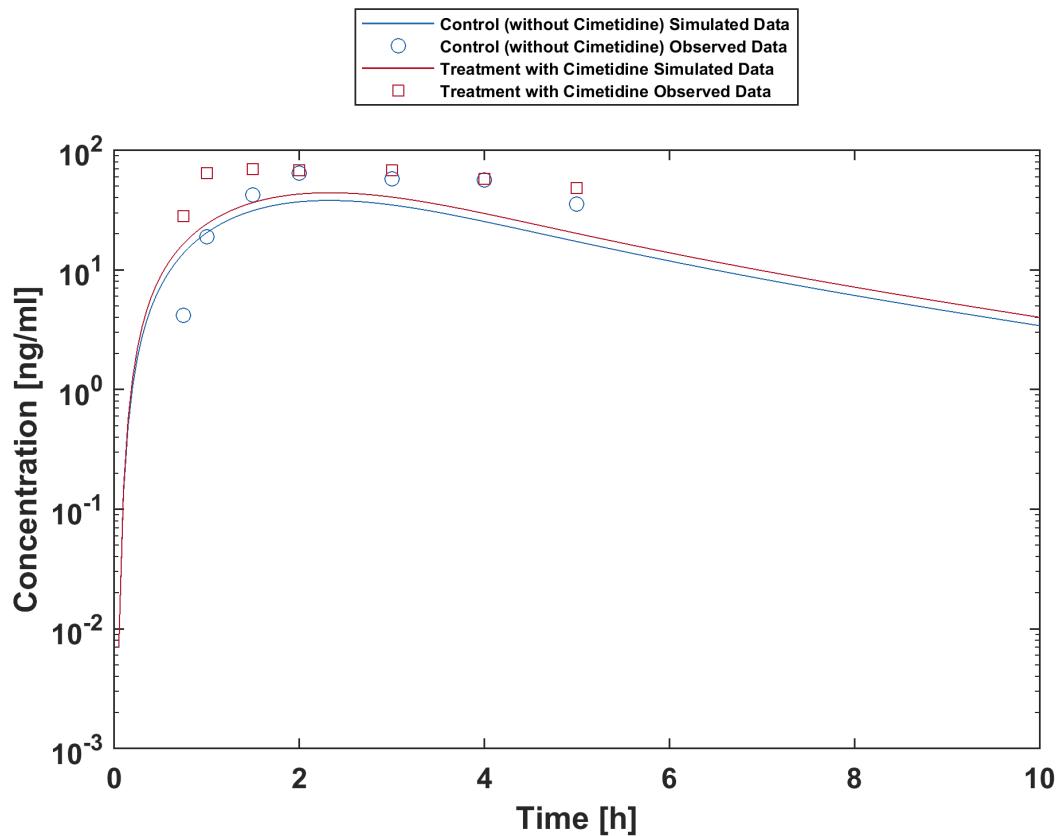
Greenblatt 1986 (midazolam PO)



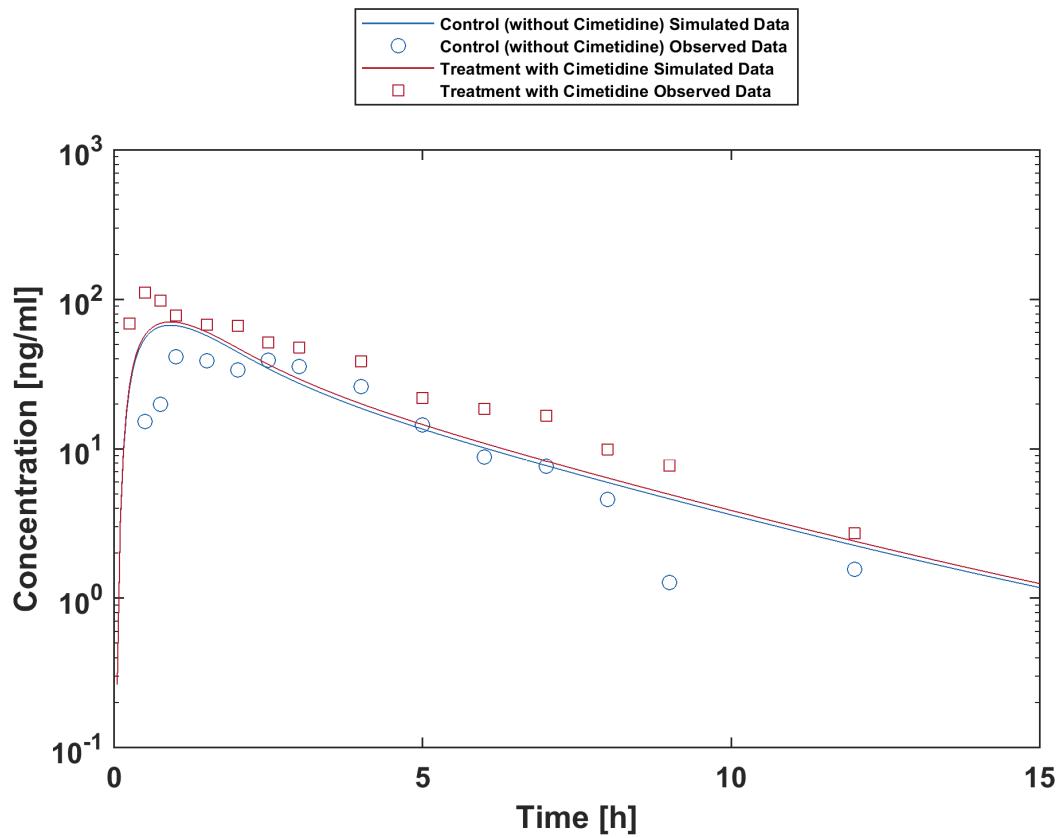
Martinez 1999



Fee 1987

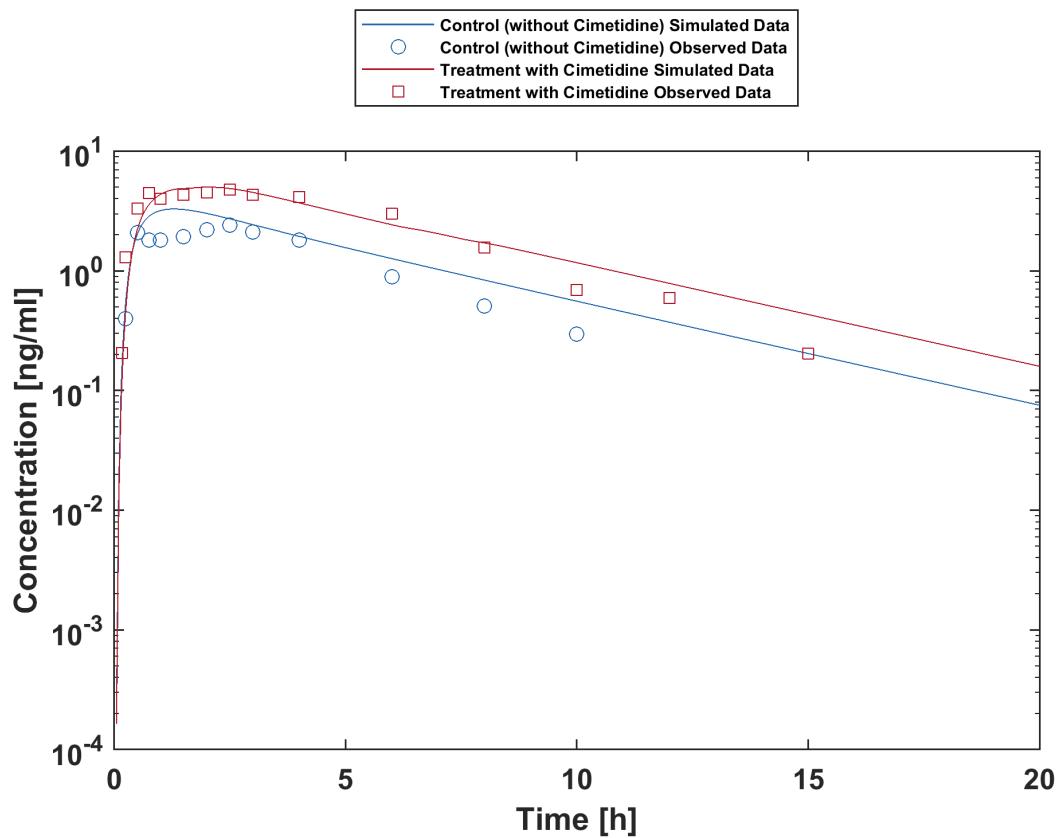


Salonen 1986

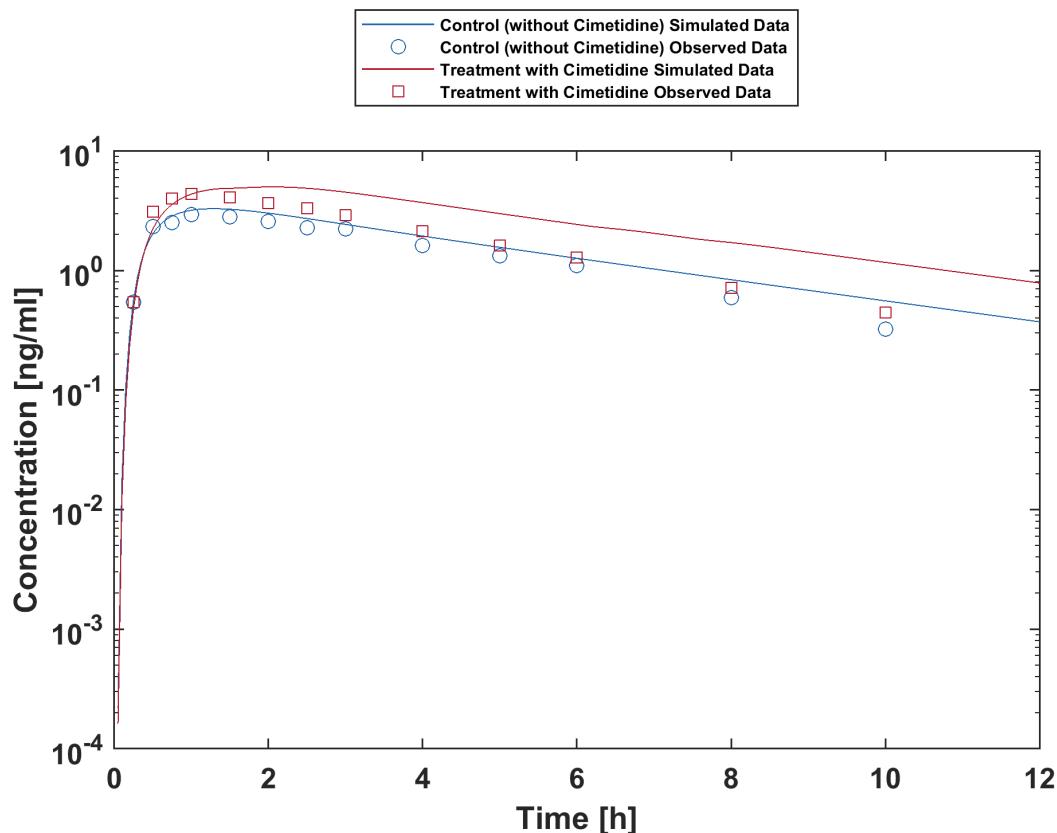


Elliott 1984

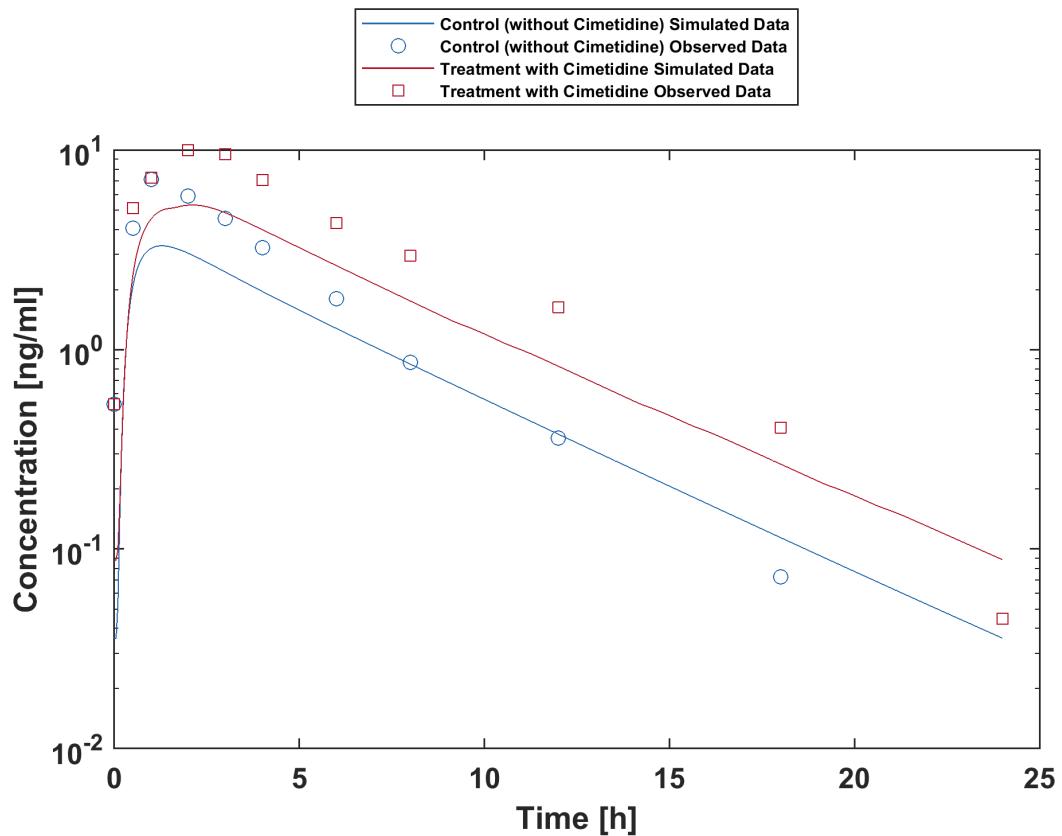
3.8 Cimetidine - Triazolam DDI



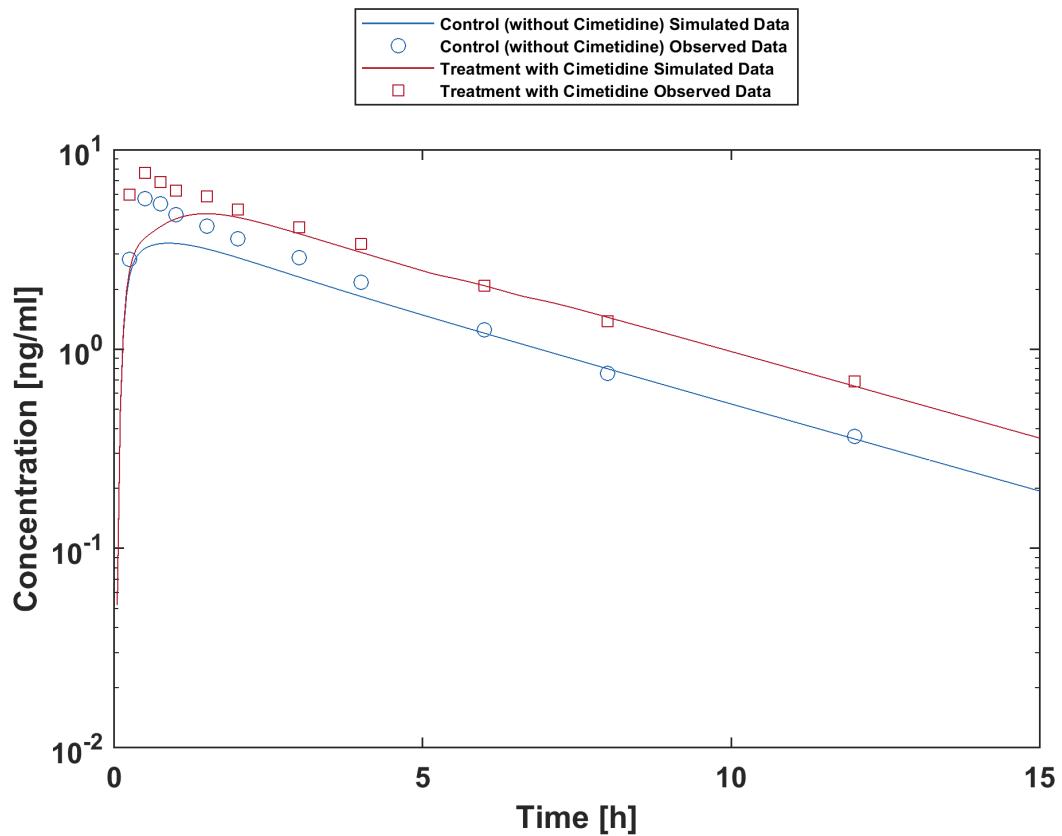
Abernethy 1983



Friedman 1988

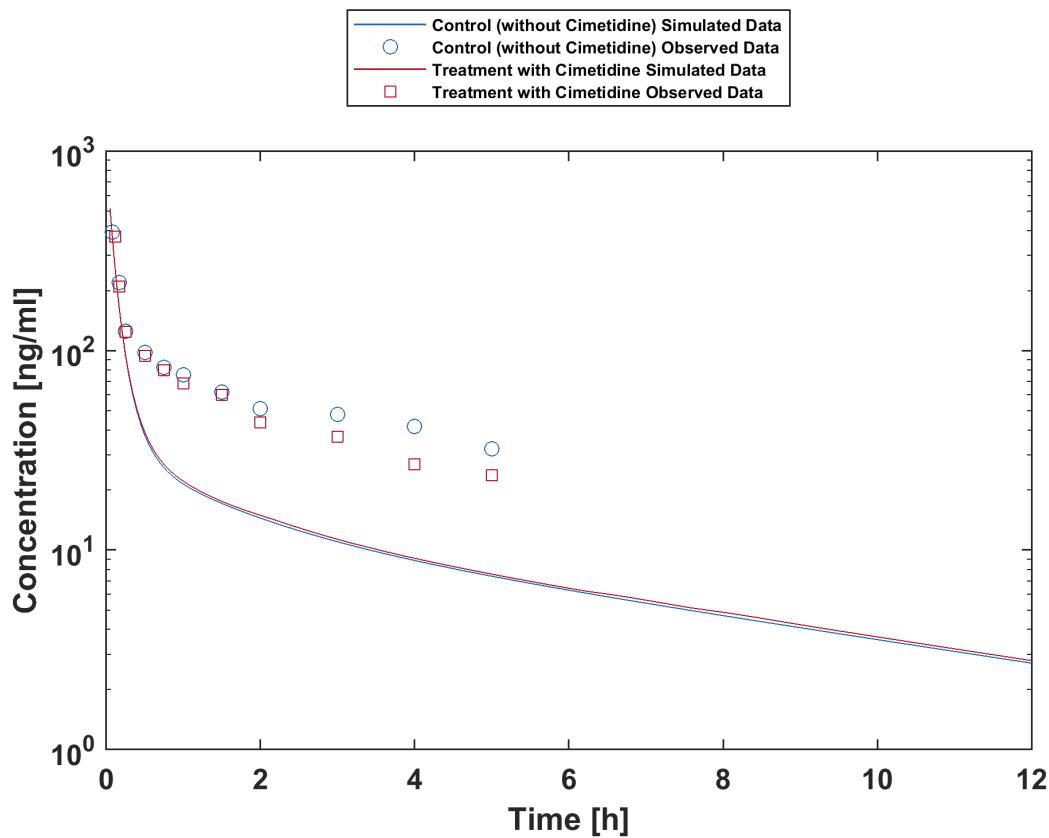


Pourbaix 1985

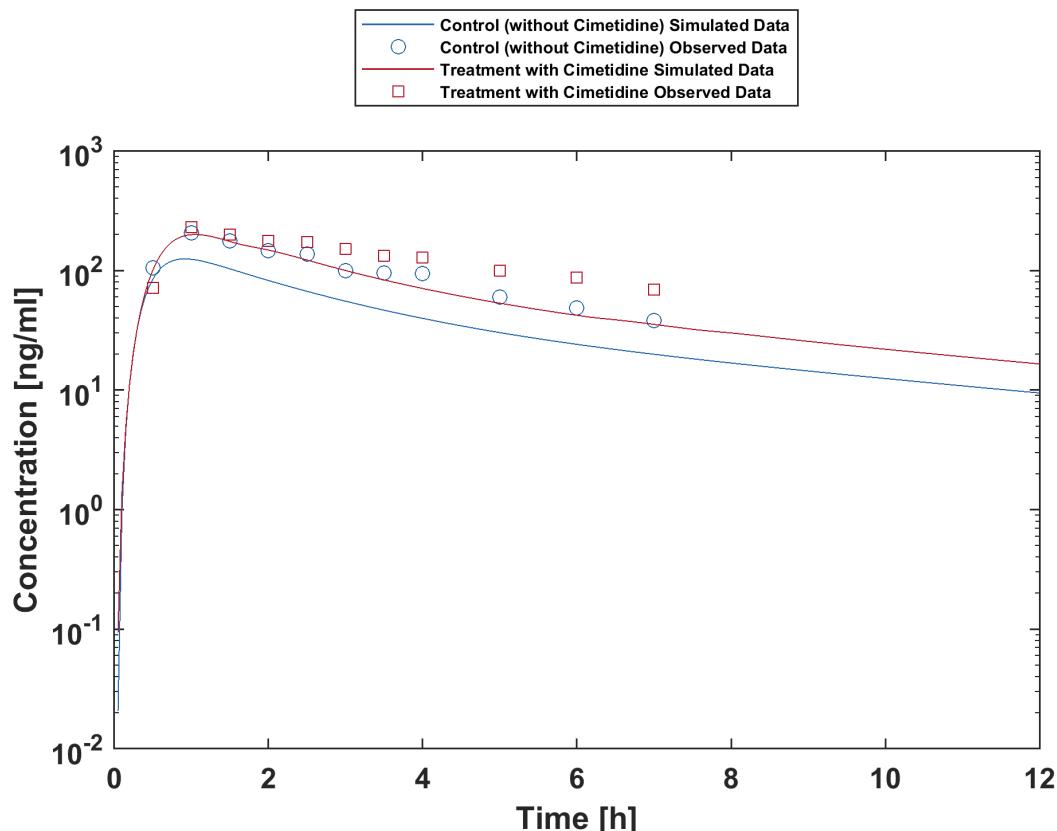


Cox 1986

3.9 Cimetidine - Verapamil DDI

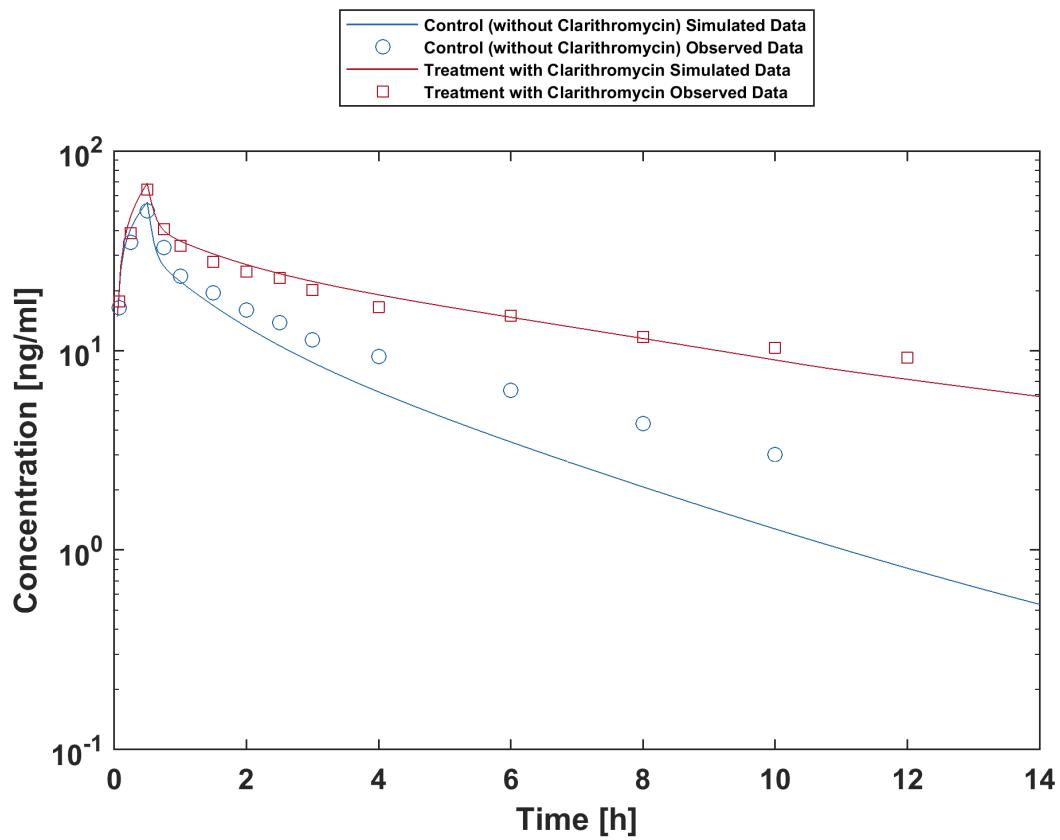


Smith 1984 (verapamil IV)

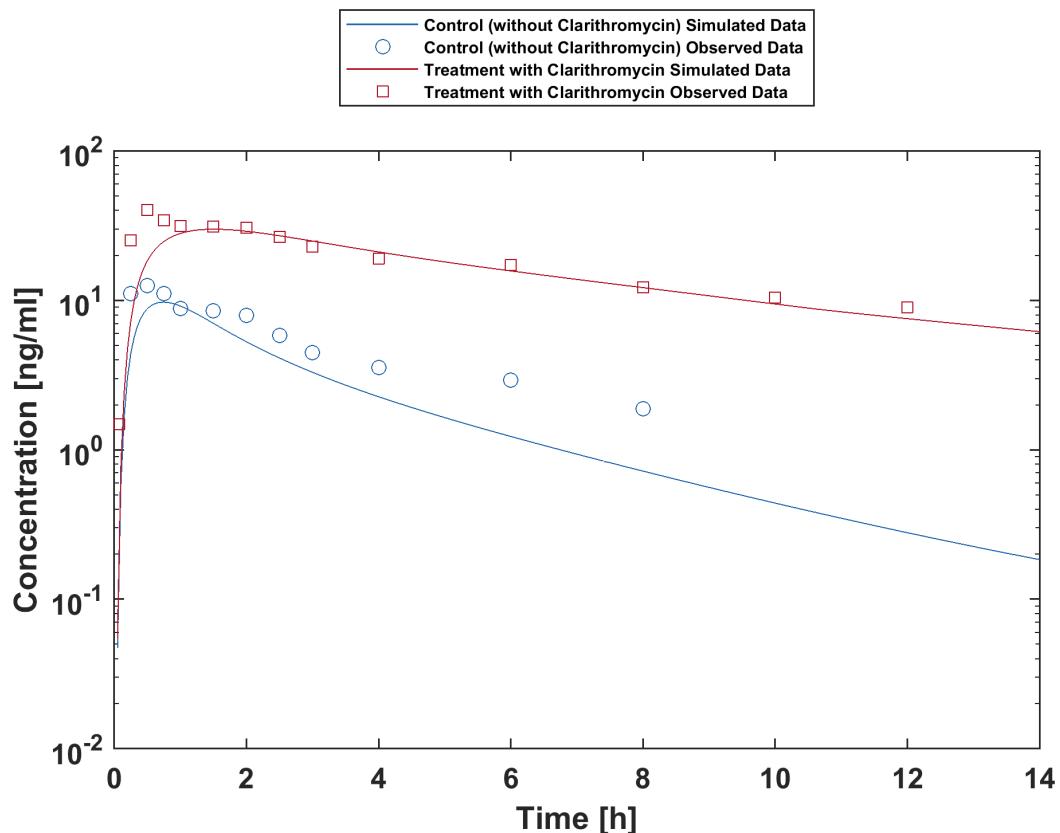


Smith 1984 (verapamil PO)

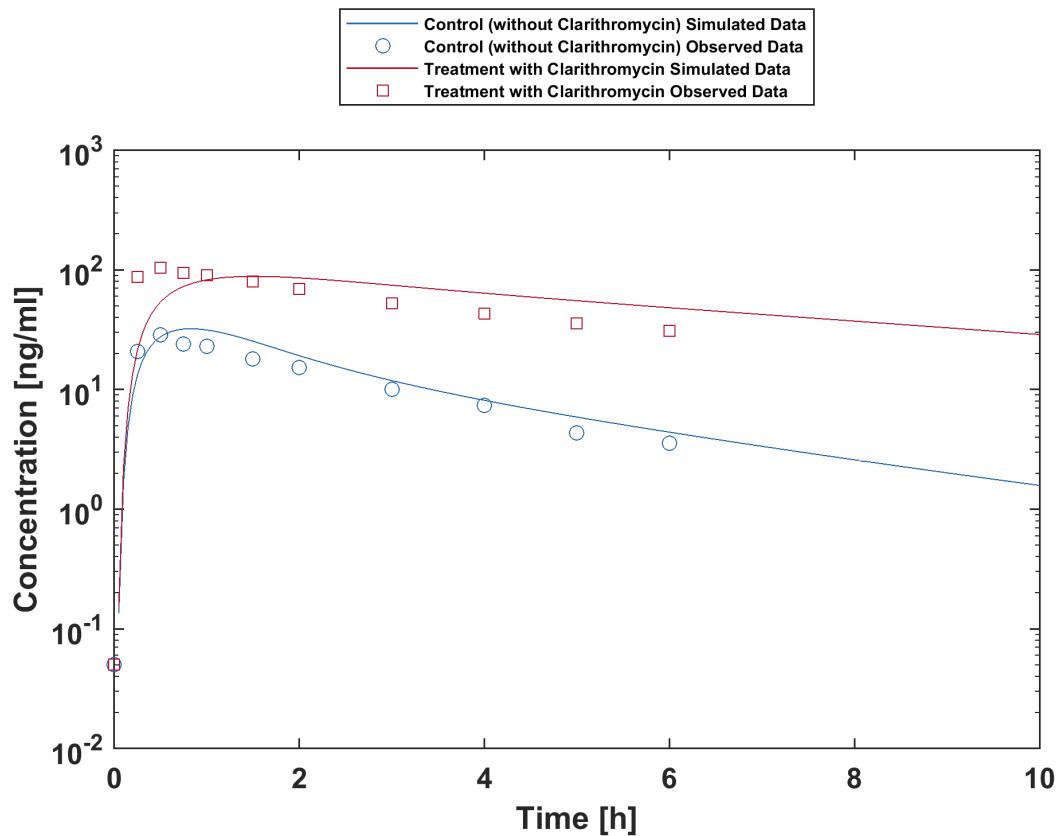
3.10 Clarithromycin - Midazolam DDI



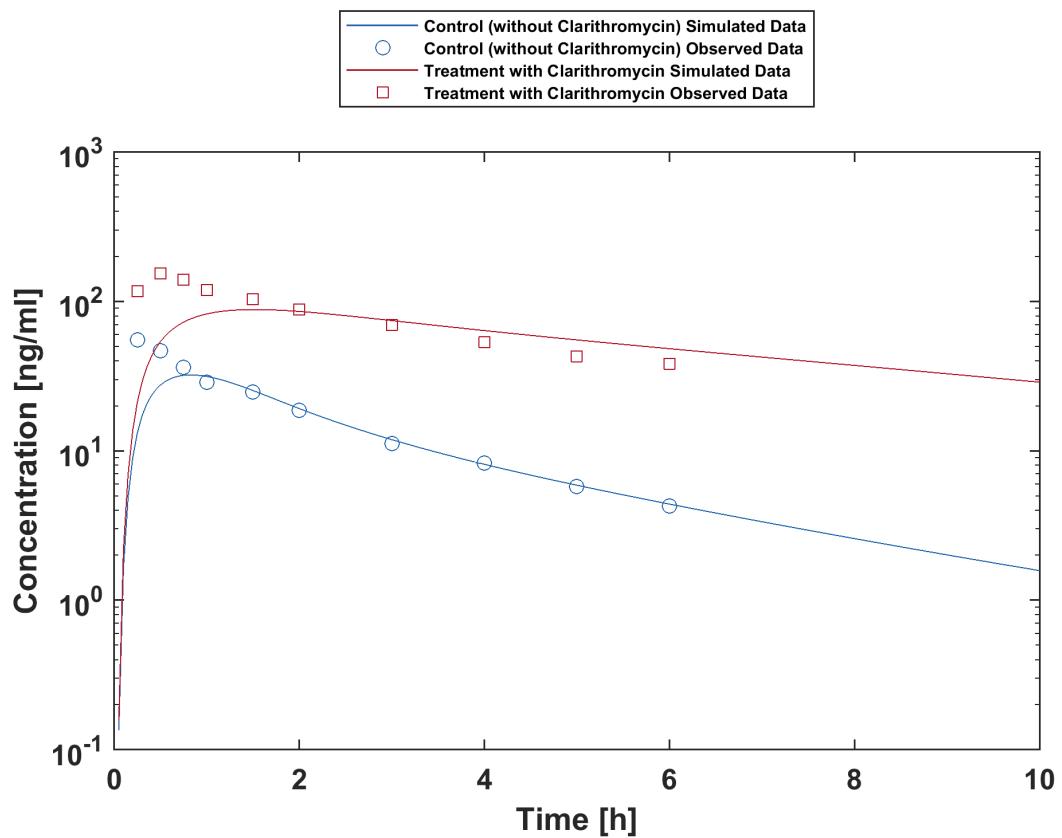
Gorski 1998 (midazolam IV)



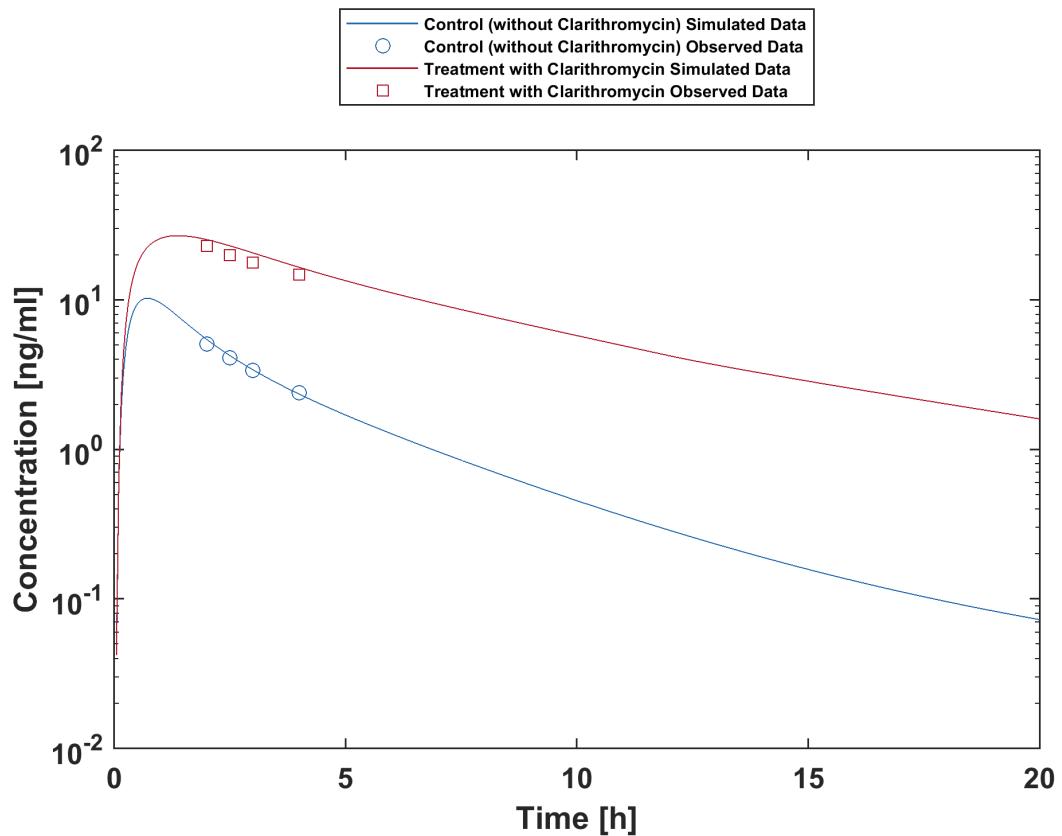
Gorski 1998 (midazolam po)



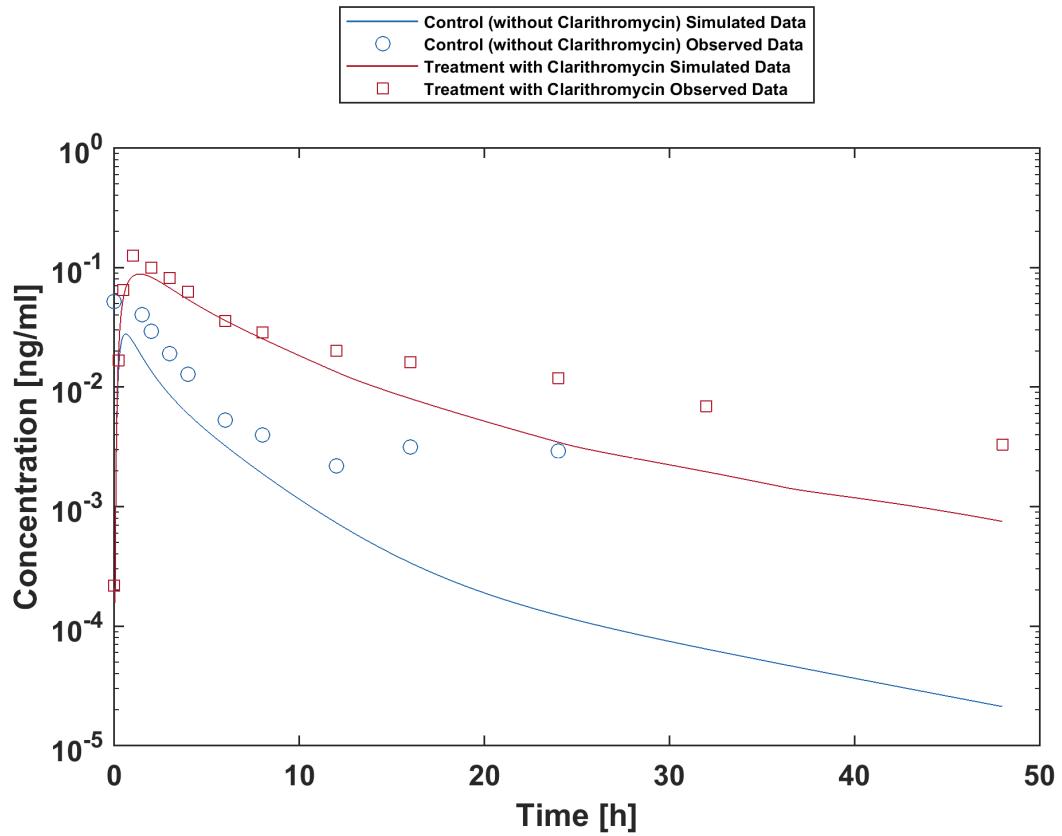
Gurley 2006



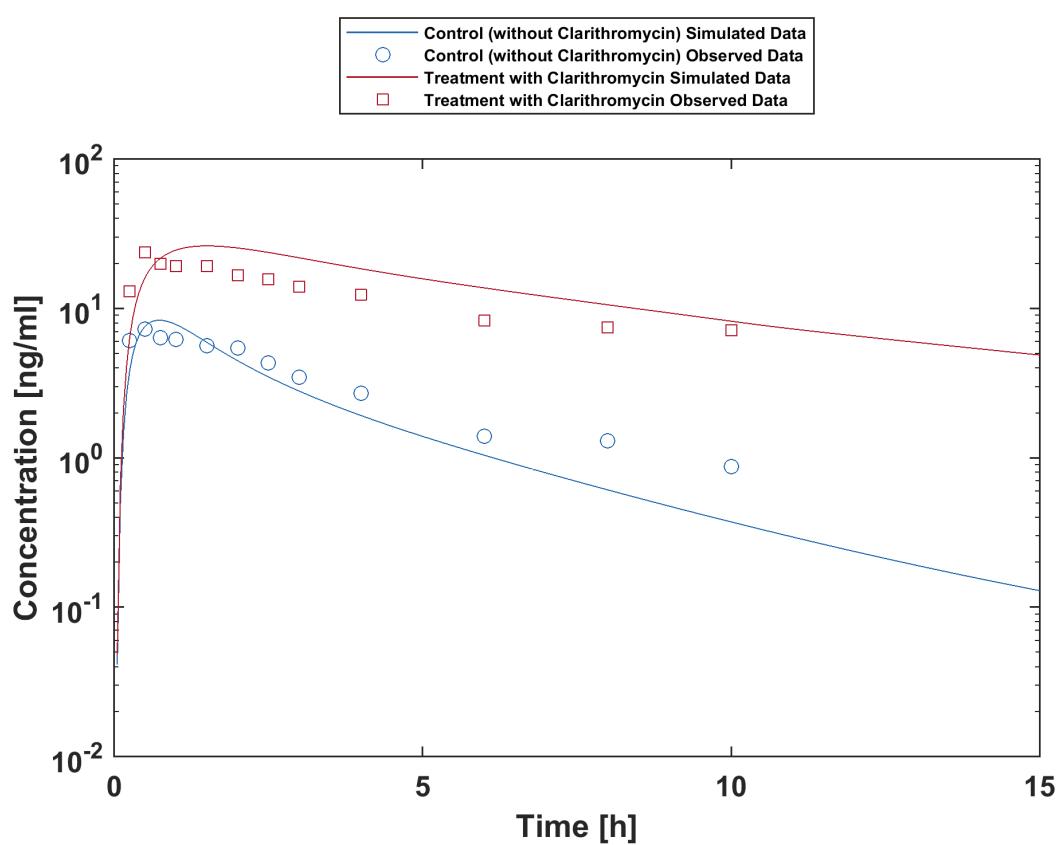
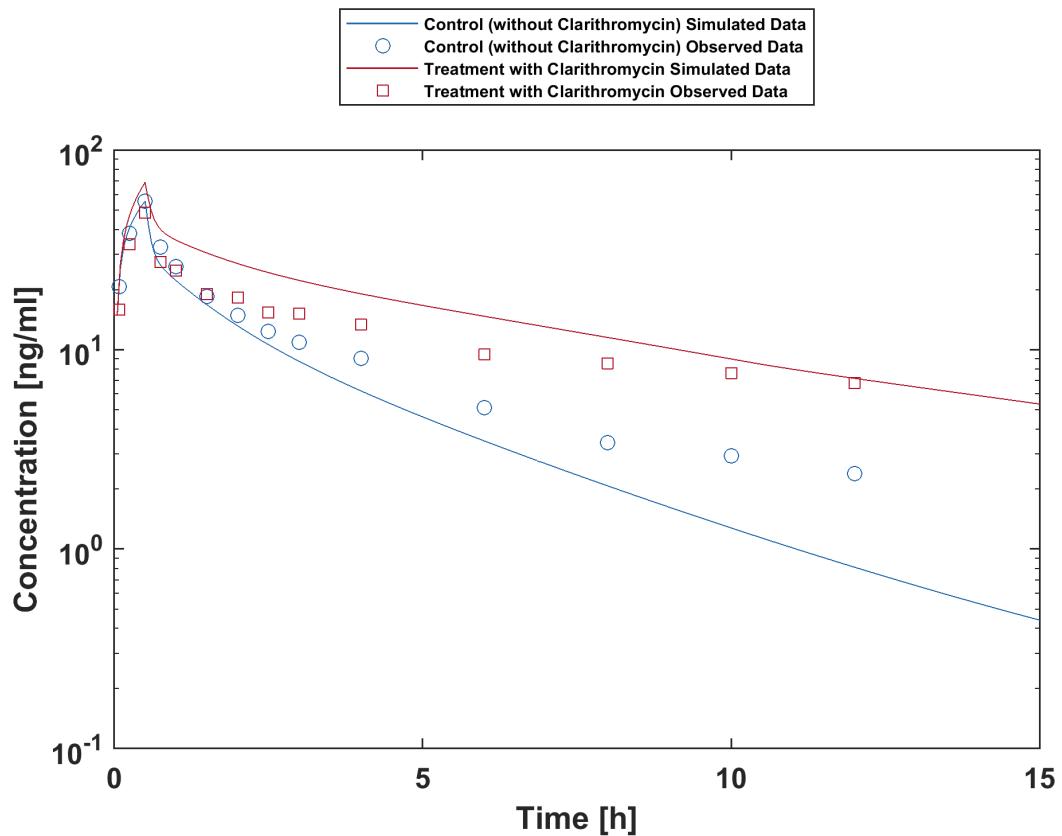
Gurley 2008a

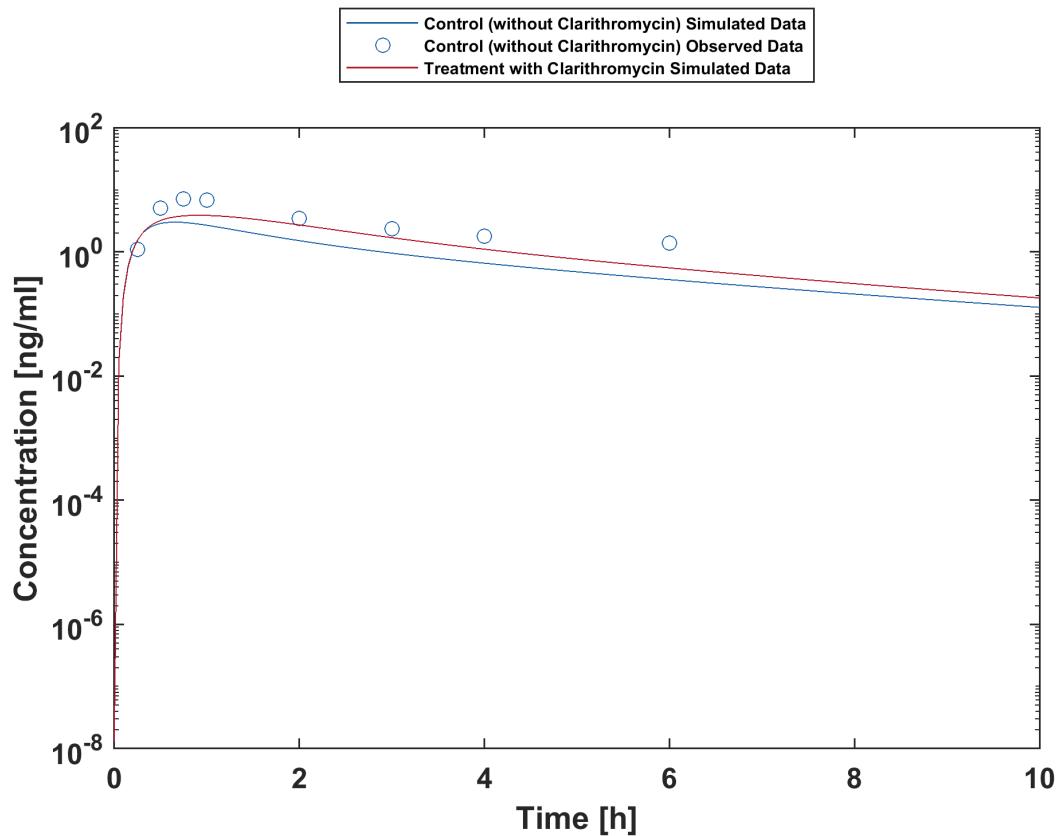


Markert 2013

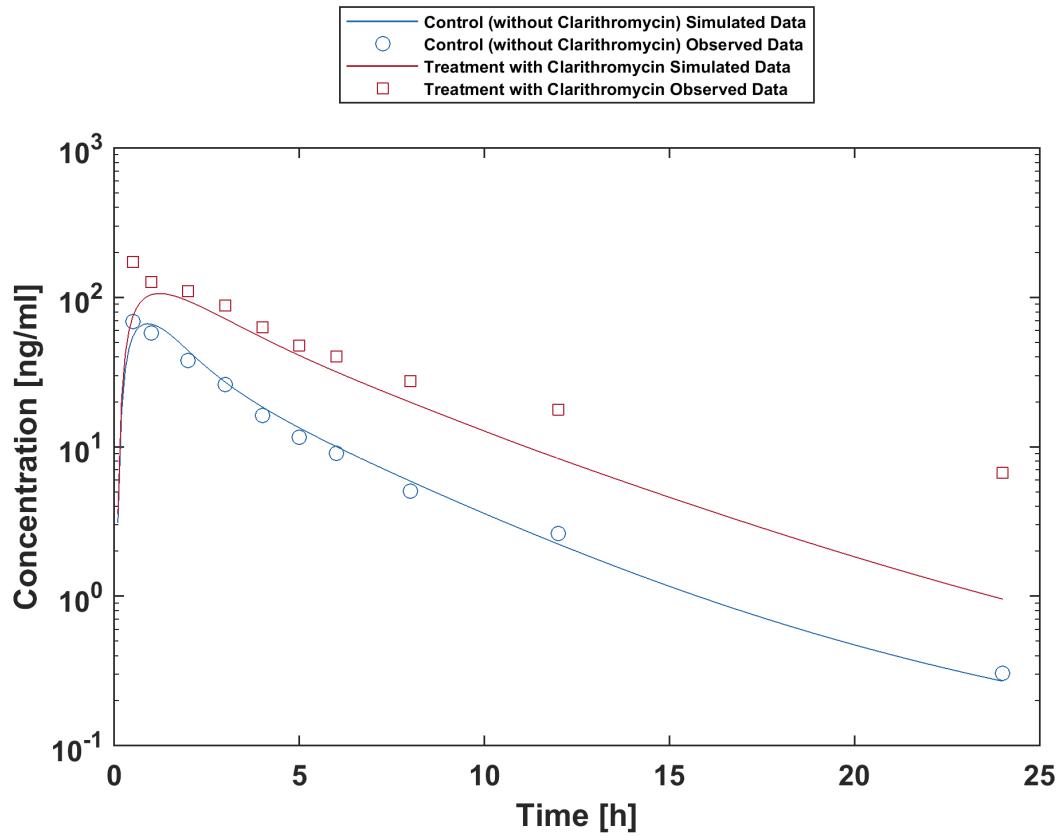


Pruksaritanont 2017



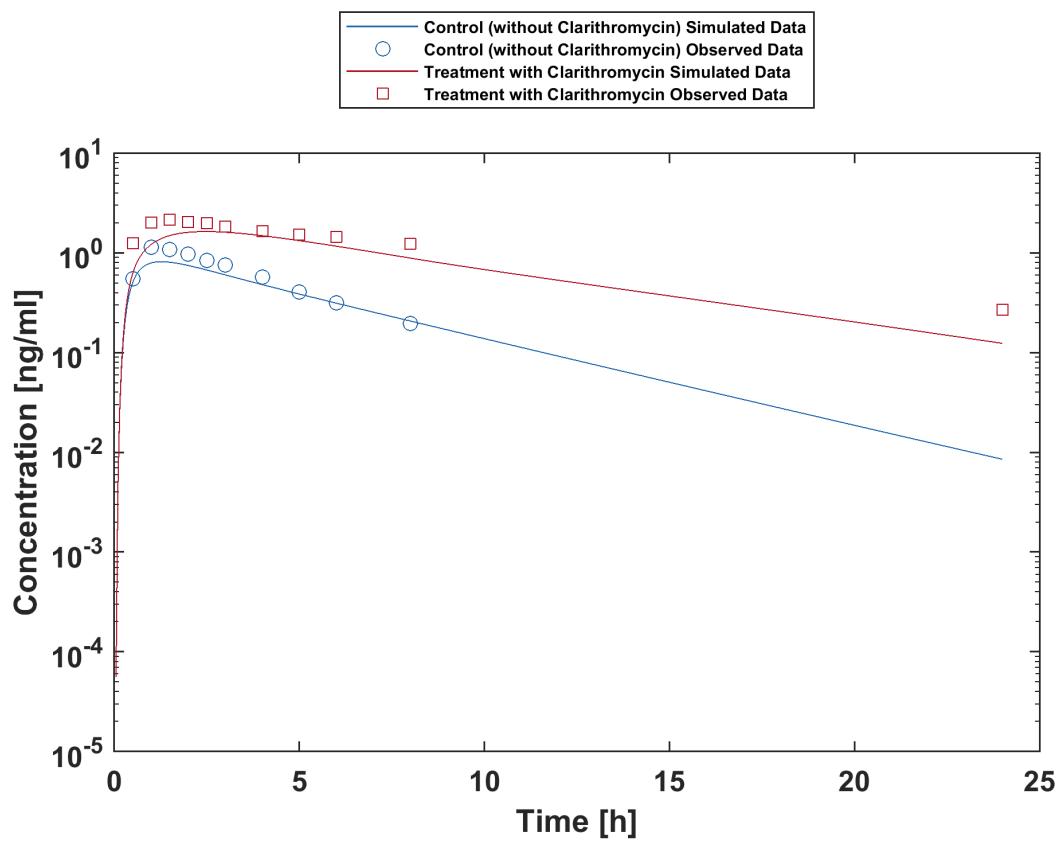


van Dyk 2018



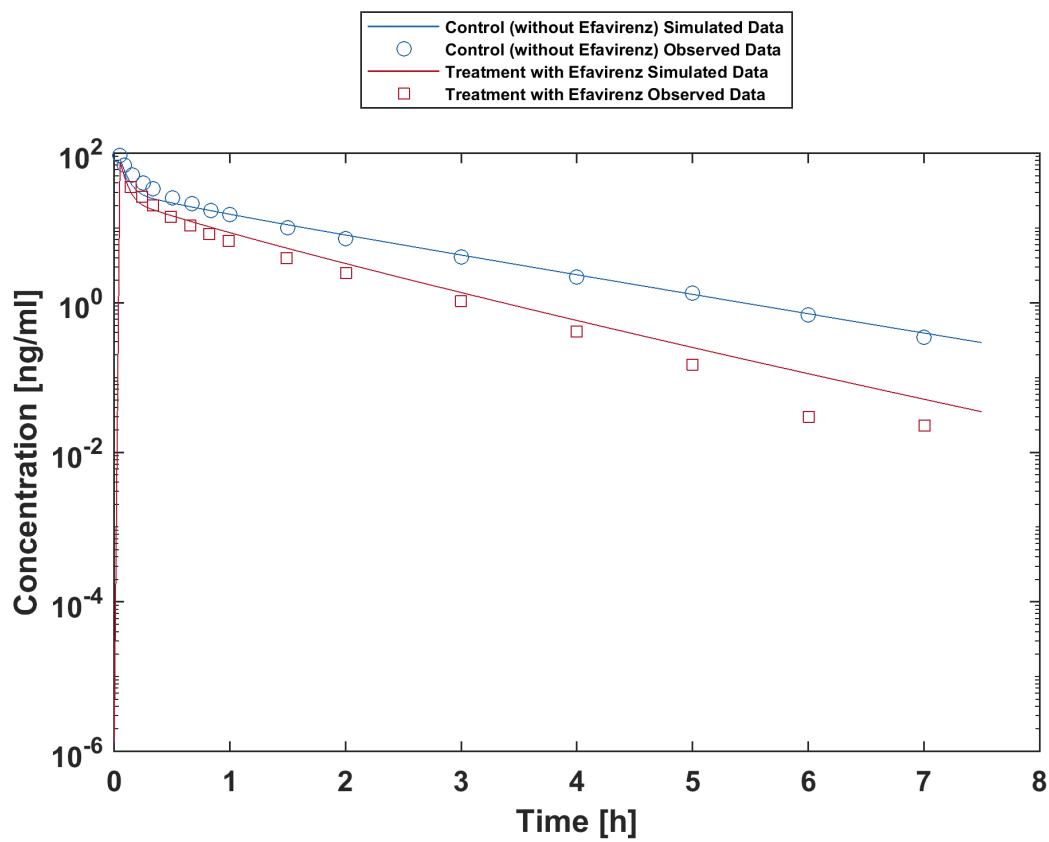
Yeates 1996

3.11 Clarithromycin - Triazolam DDI

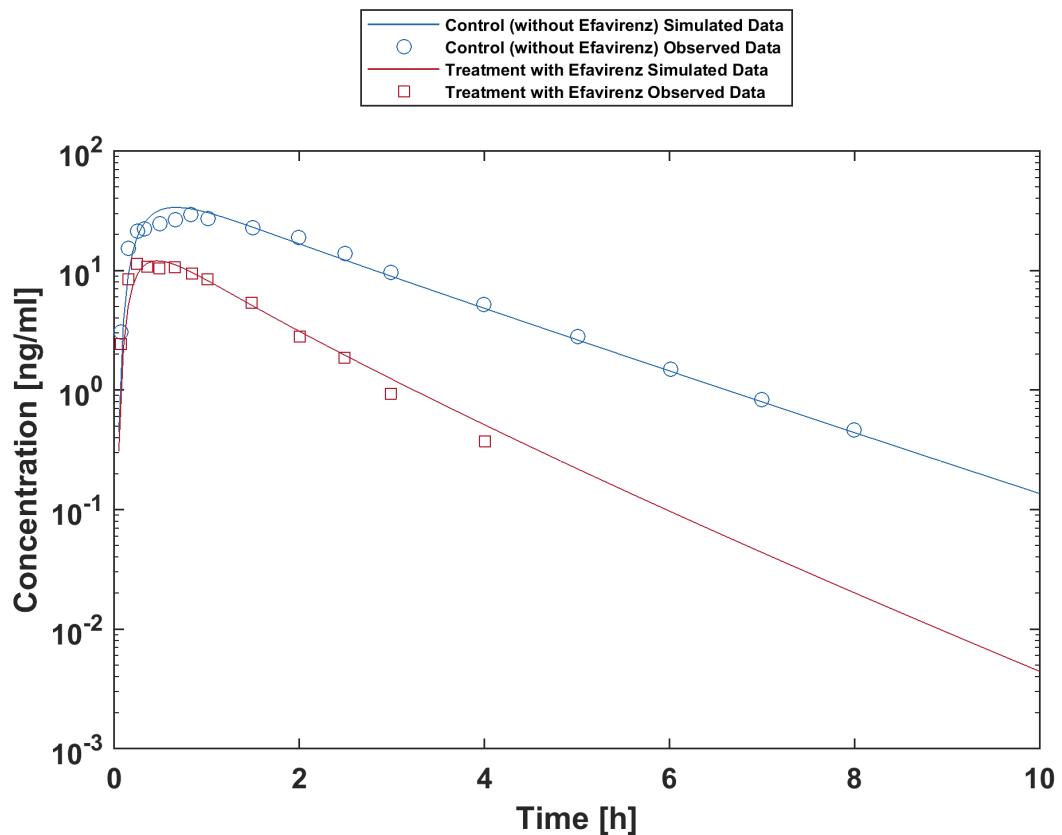


Greenblatt 1998a

3.12 Efavirenz - Alfentanil DDI

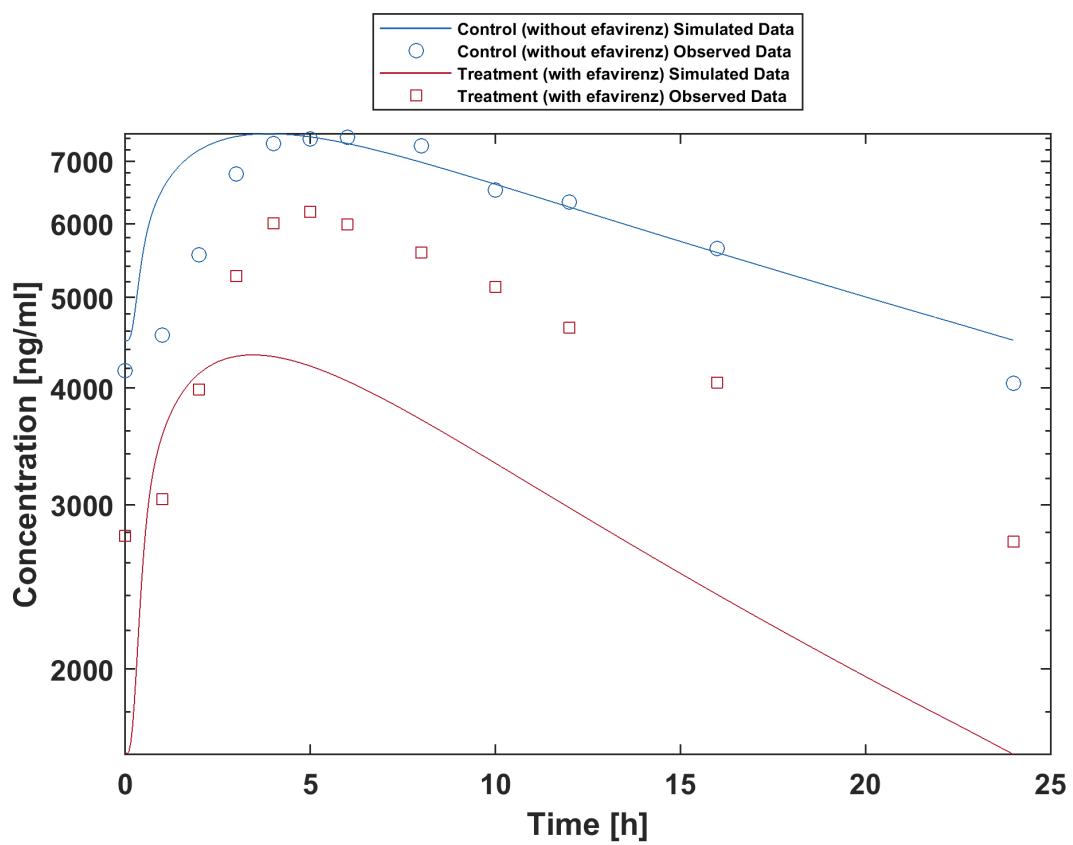


Kharasch 2012 IV



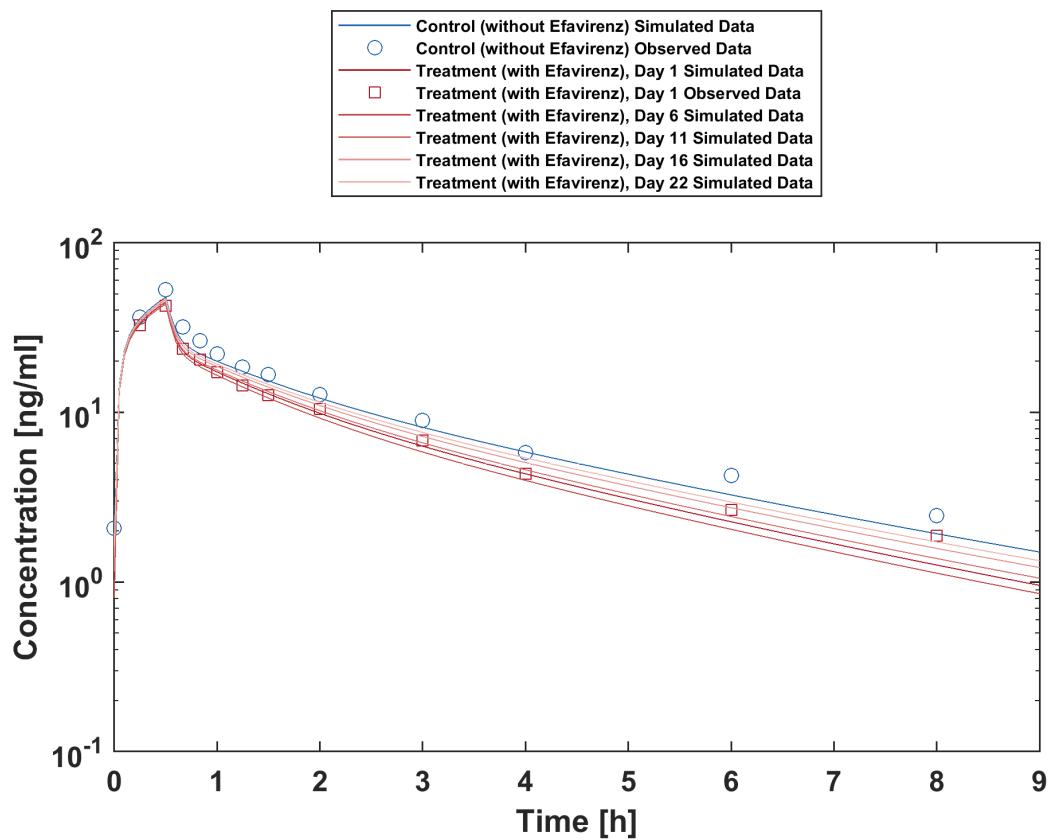
Kharasch 2012 PO

3.13 Efavirenz - Carbamazepine DDI

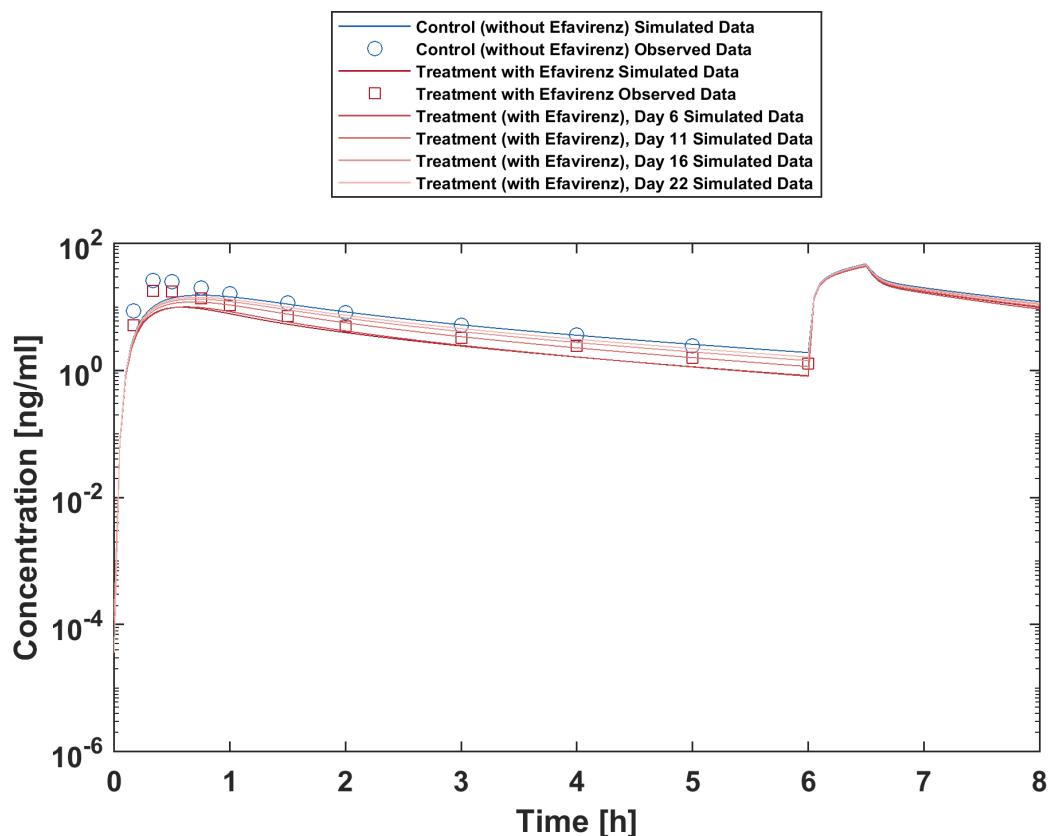


Ji 2008 (Arm 2, Perpetrator: Efavirenz, Victim: Carbamazepine)

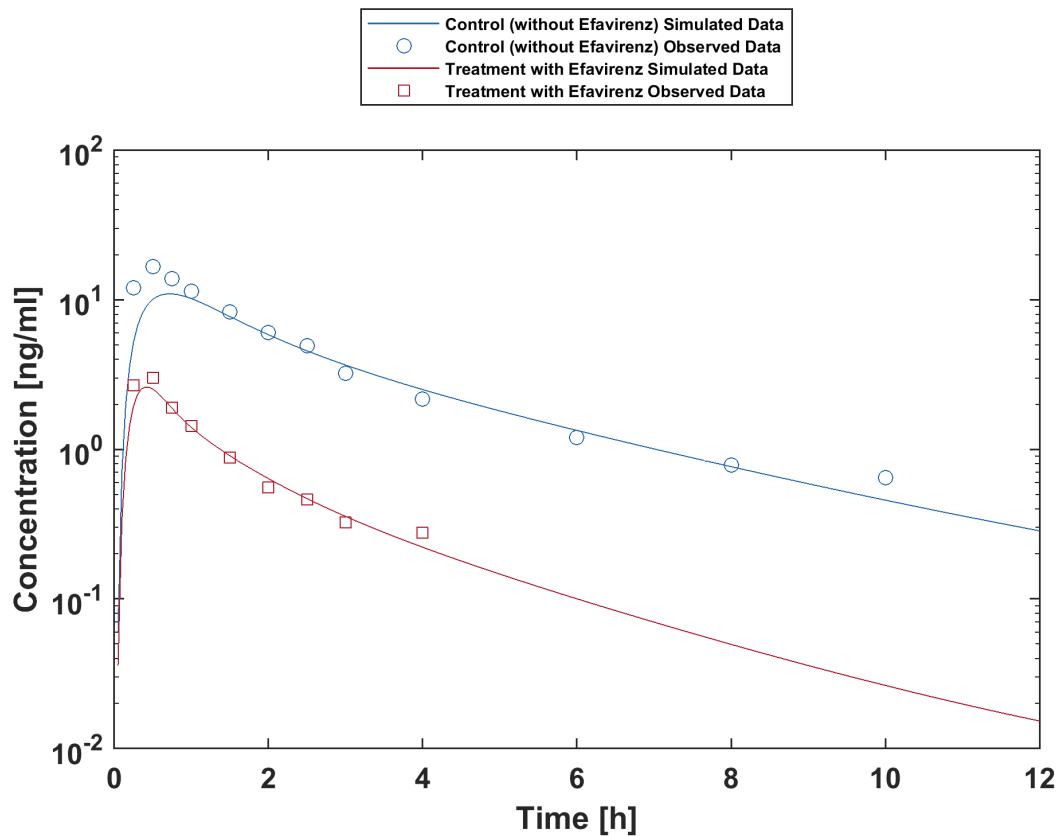
3.14 Efavirenz - Midazolam DDI



Mikus 2017 IV

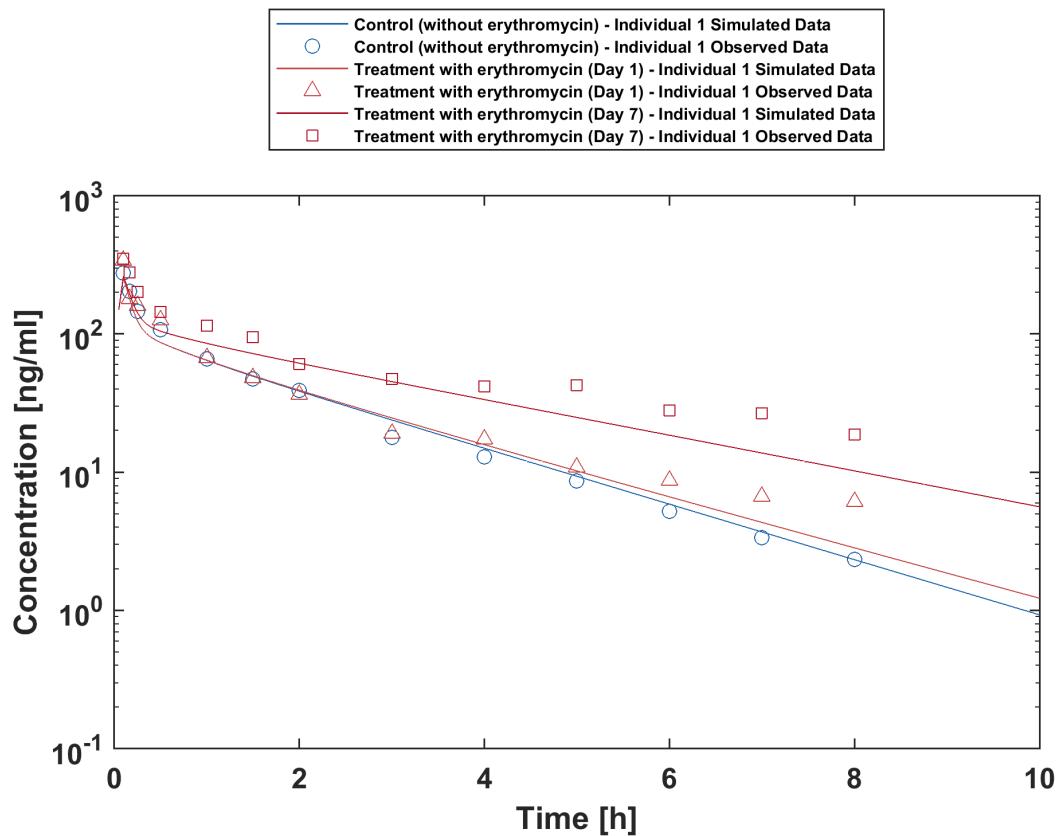


Mikus 2017 PO

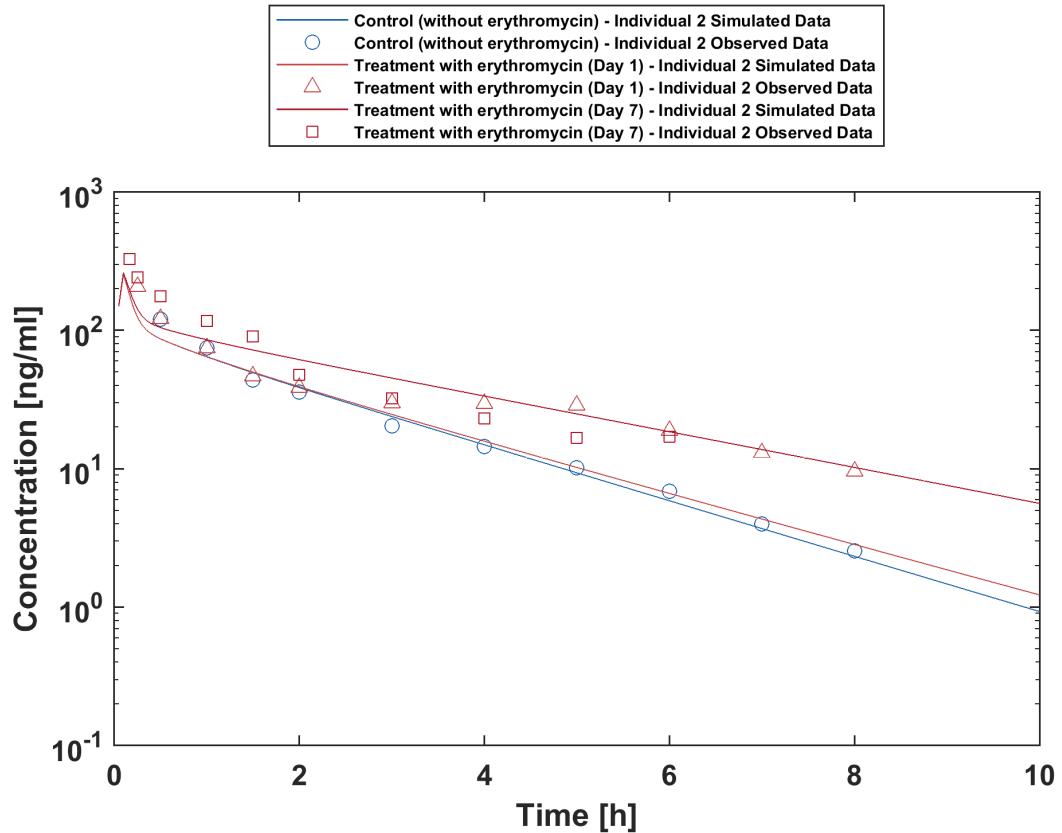


Katzenmaier 2010

3.15 Erythromycin - Alfentanil DDI

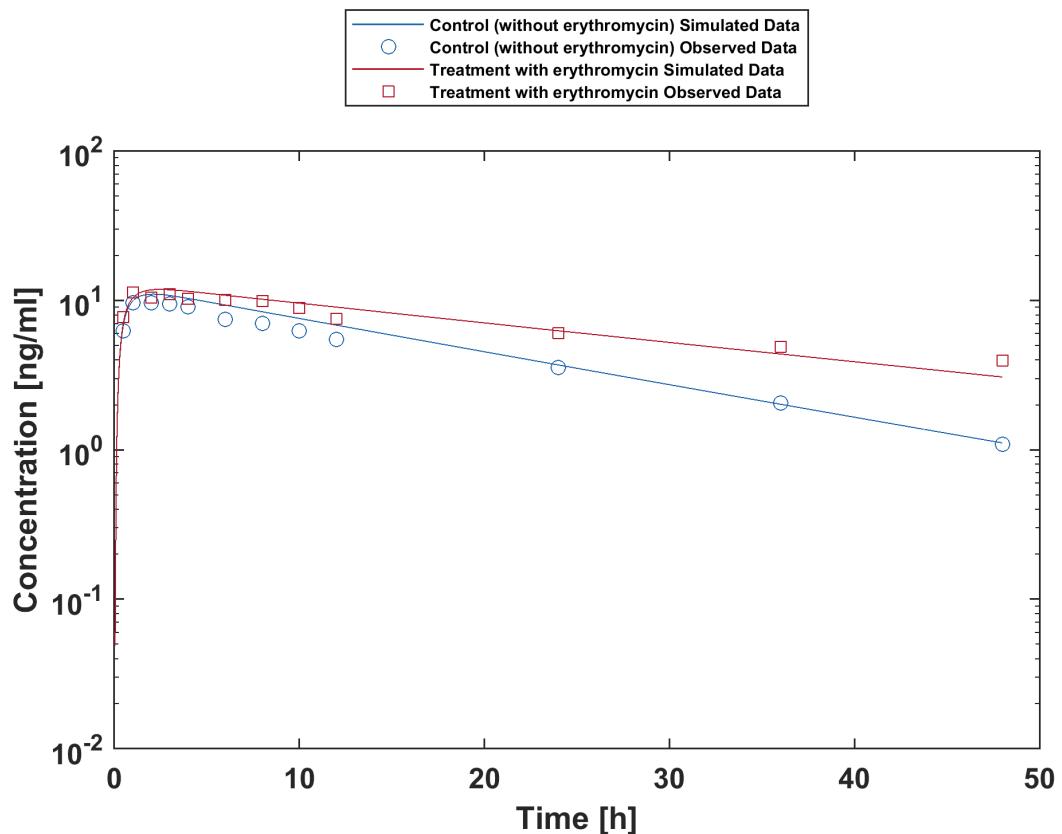


Bartkowski 1989



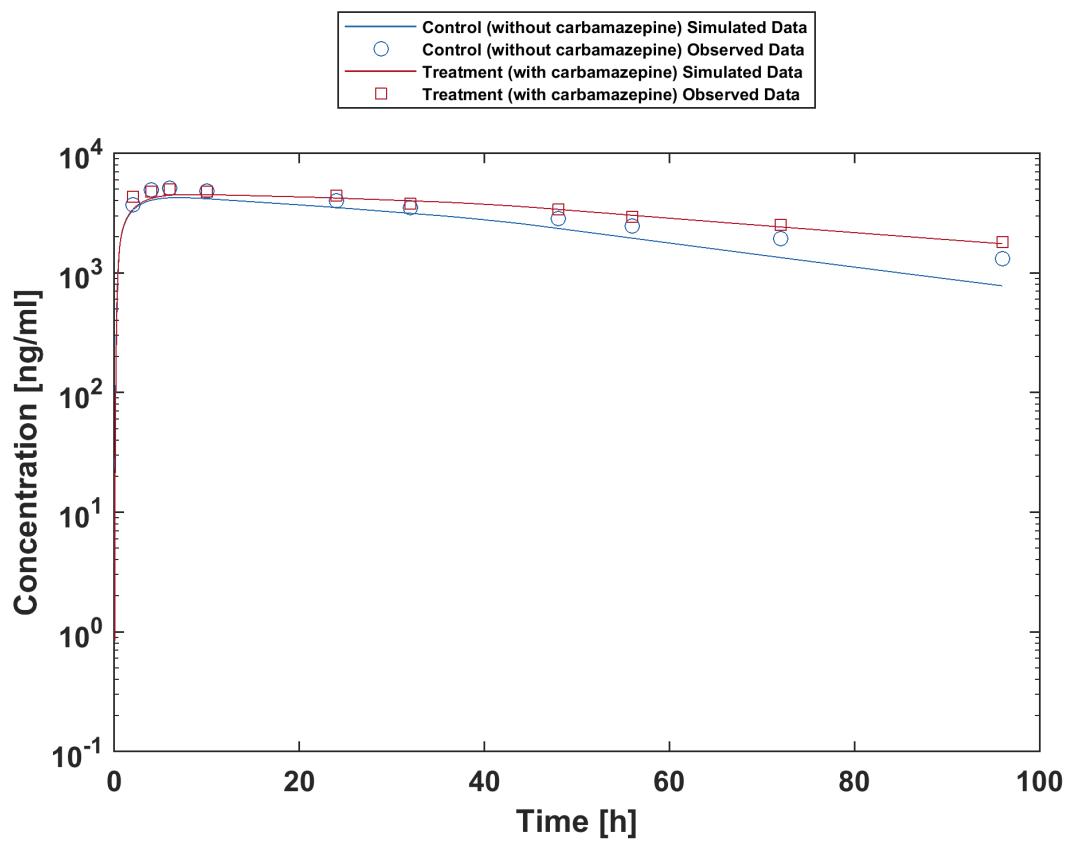
Bartkowski 1993

3.16 Erythromycin - Alprazolam DDI

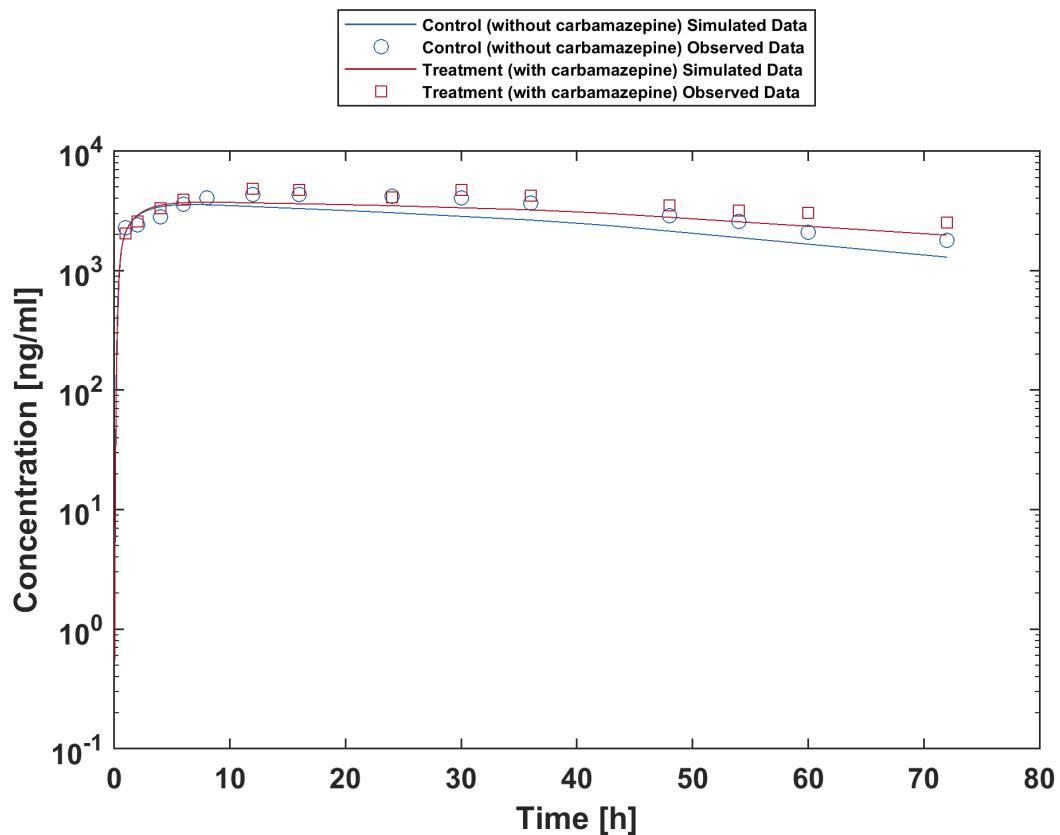


Yasui 1996

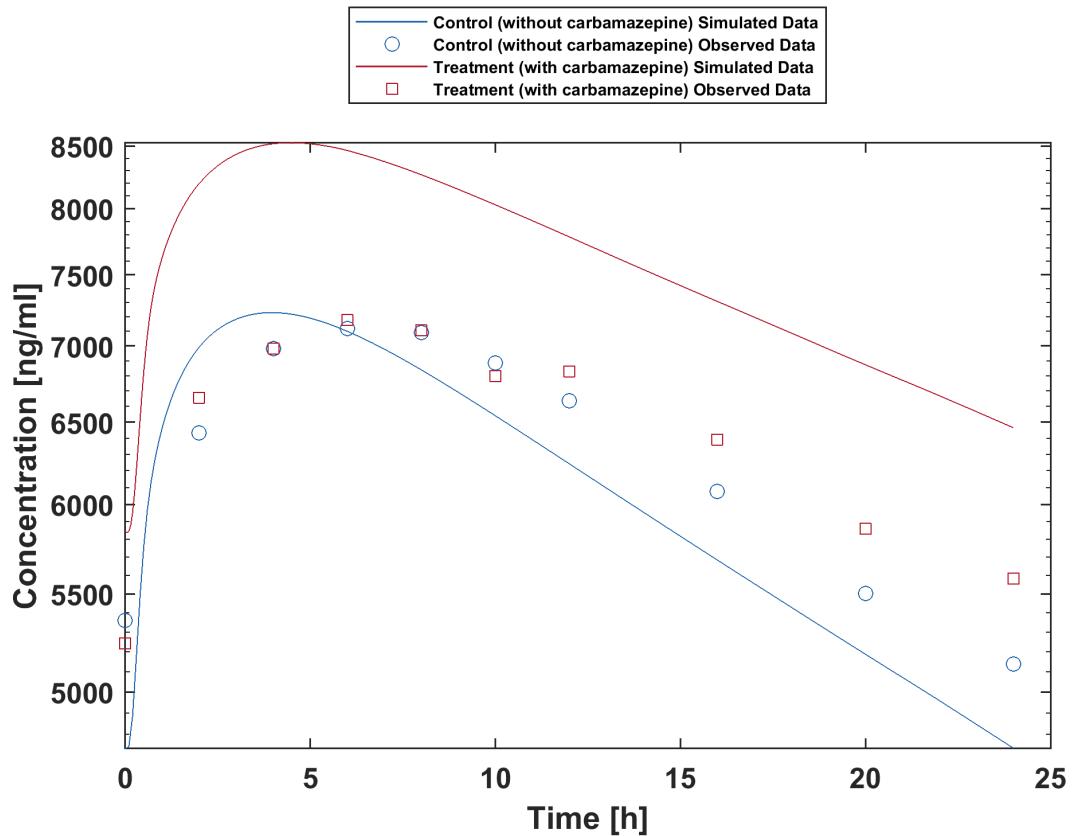
3.17 Erythromycin - Carbamazepine DDI



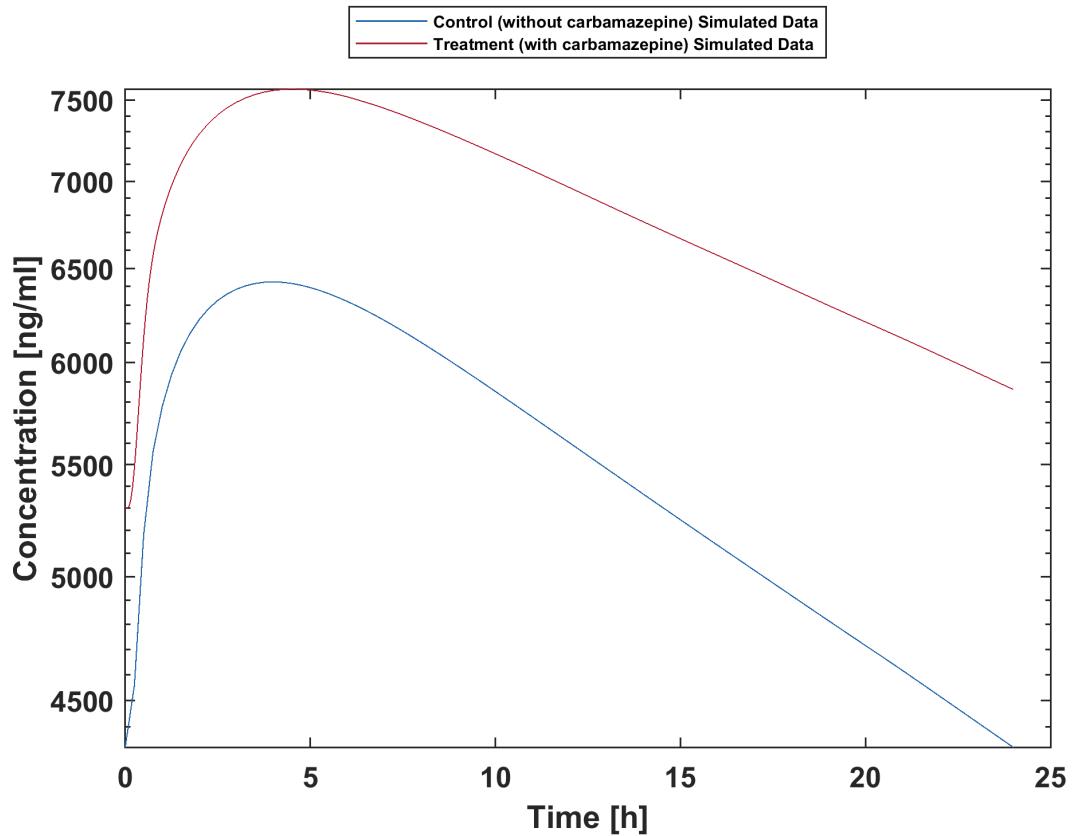
Barzaghi 1987



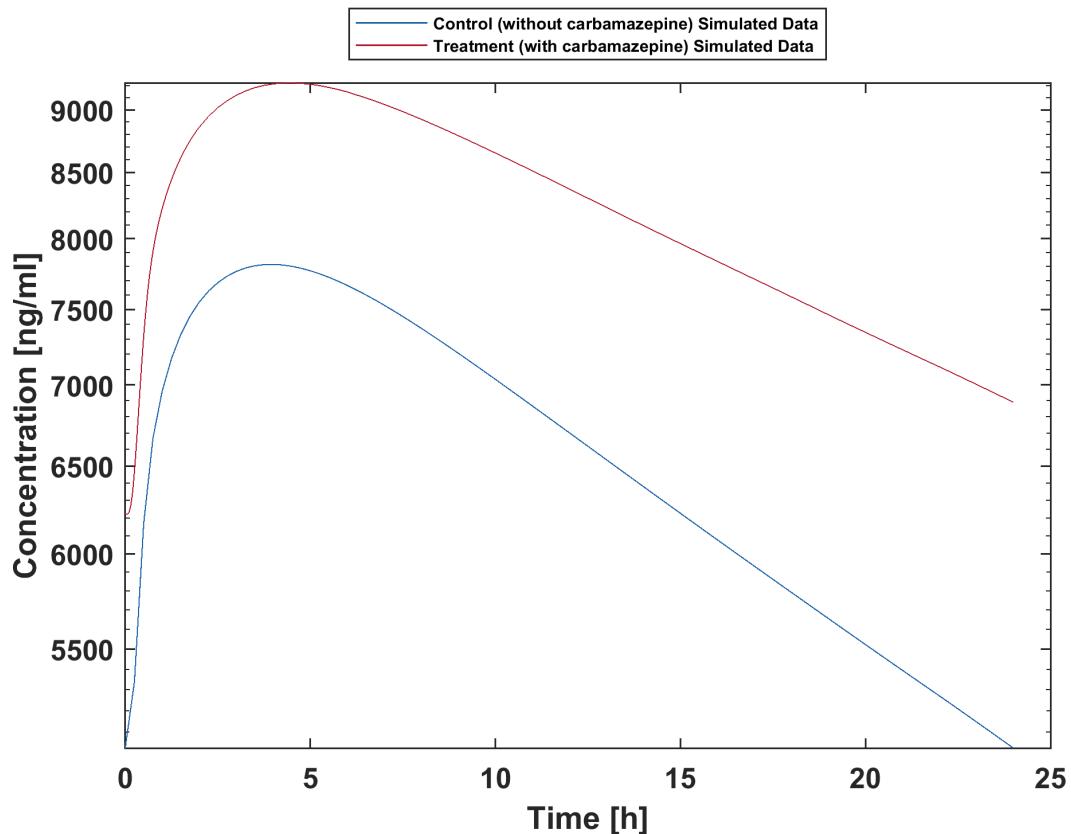
Wong 1983



Miles 1989 (average dose of 357 mg)

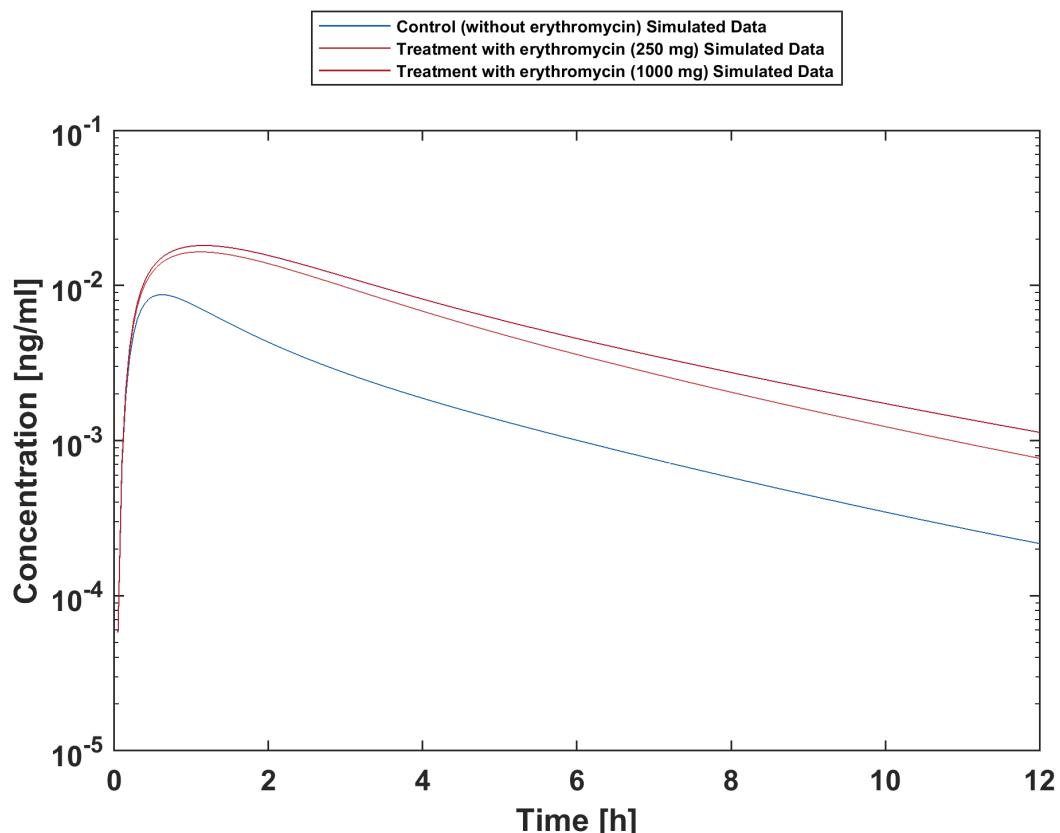


Miles 1989 (300 mg)

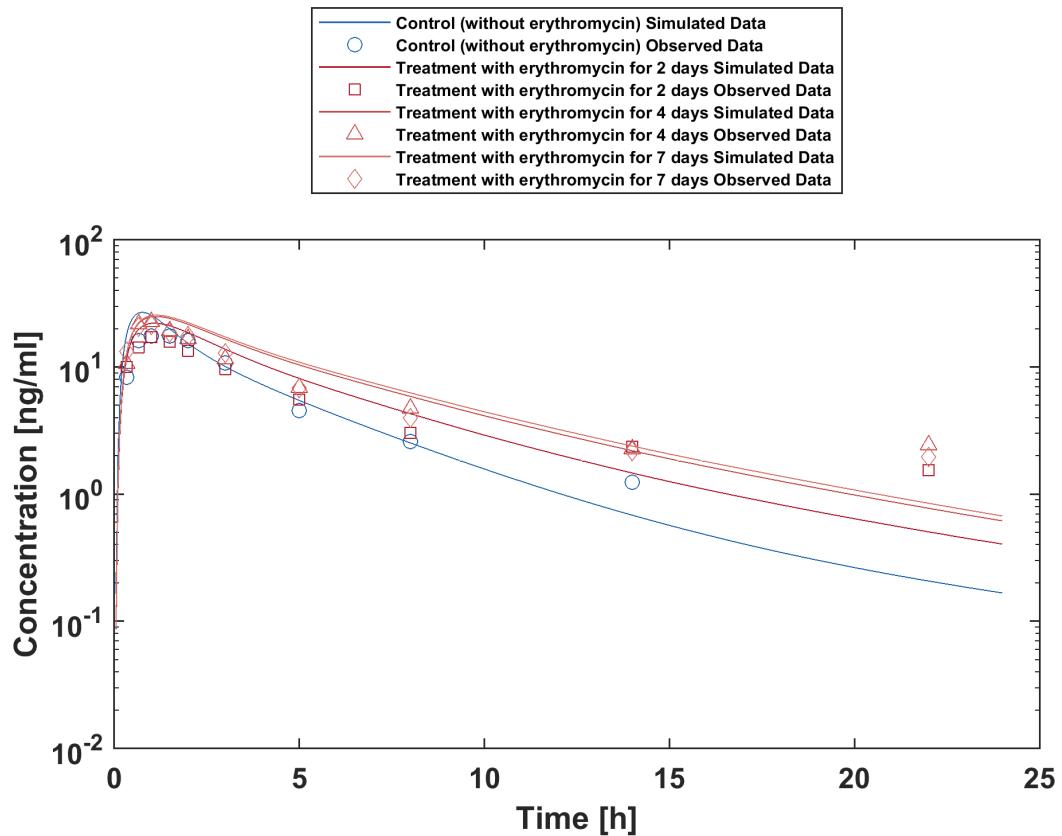


Miles 1989 (400 mg)

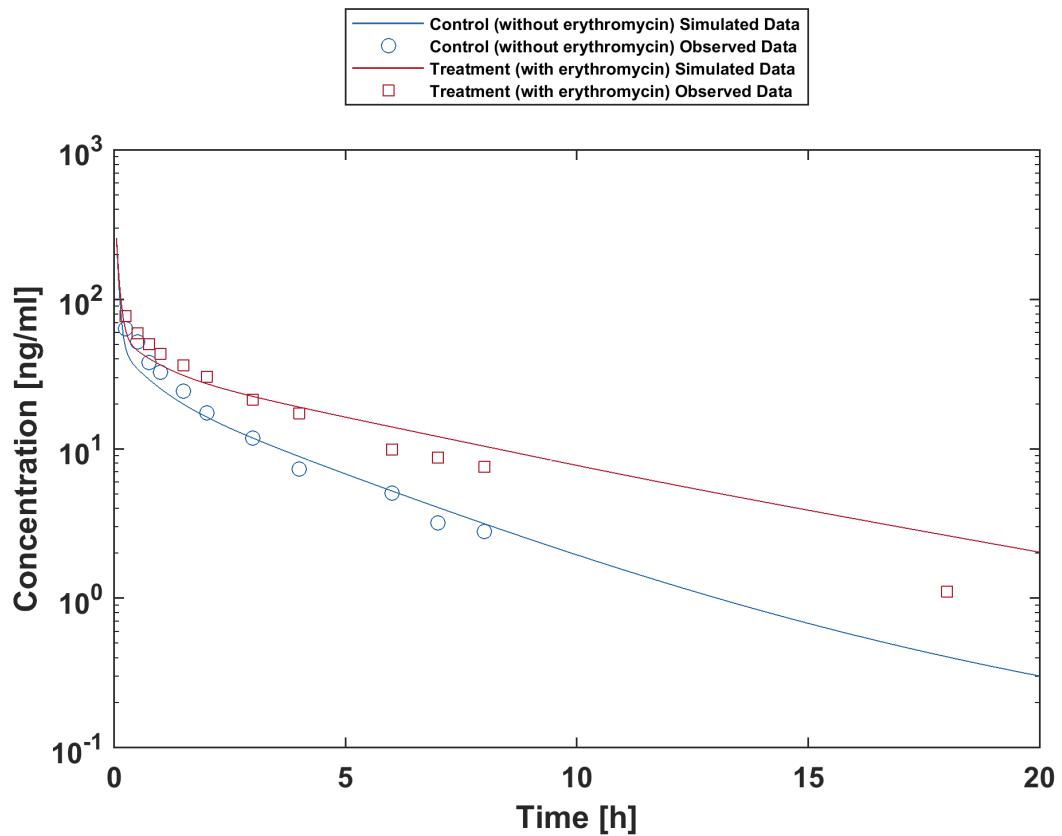
3.18 Erythromycin - Midazolam DDI



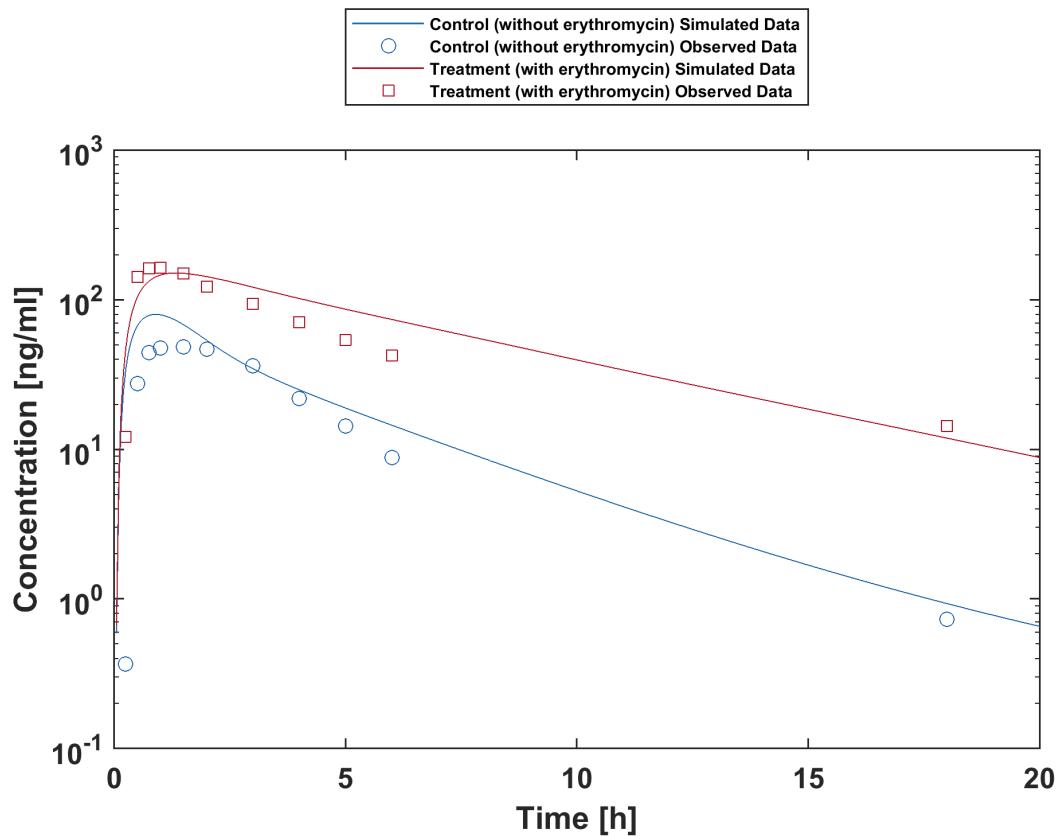
Carls 2014



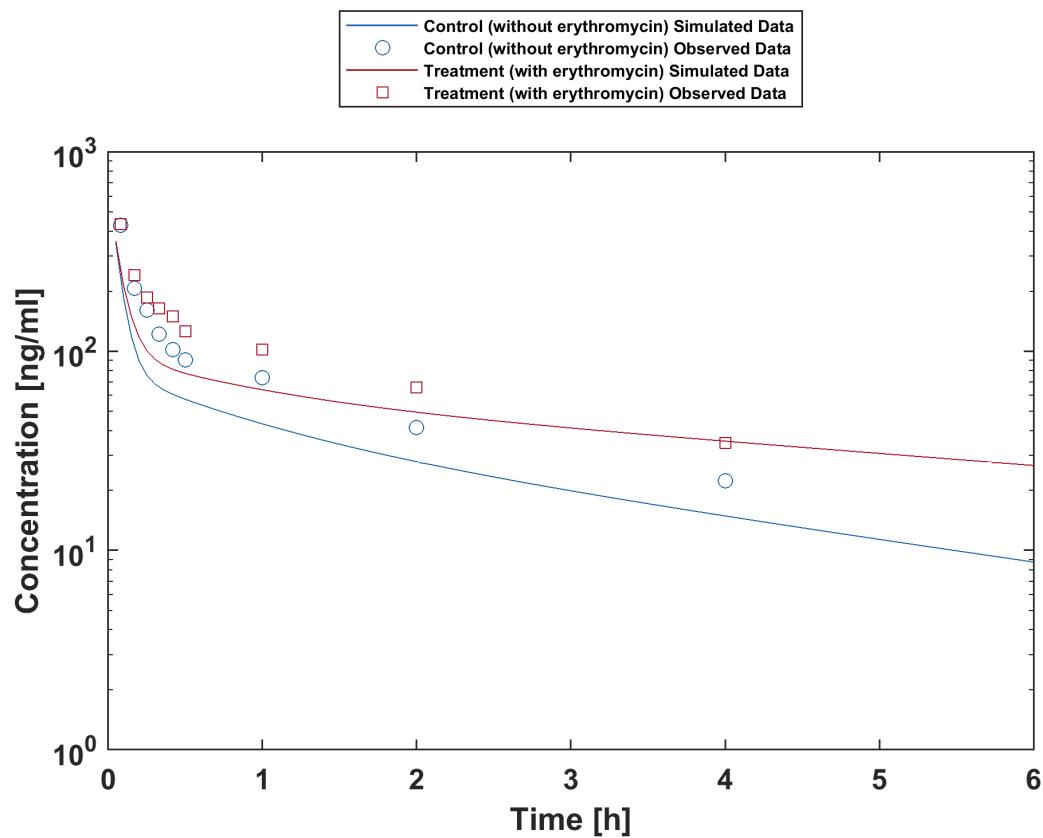
Okudaira 2007



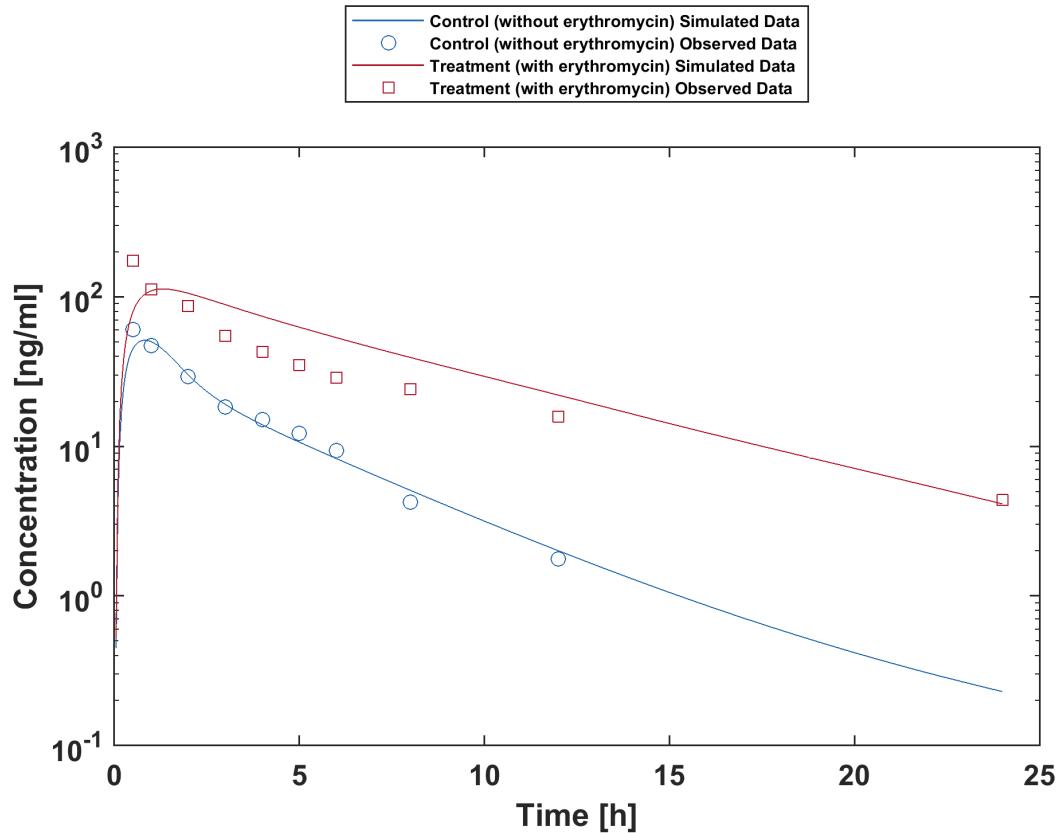
Olkola 1993 (midazolam IV)



Olkola 1993 (midazolam po)

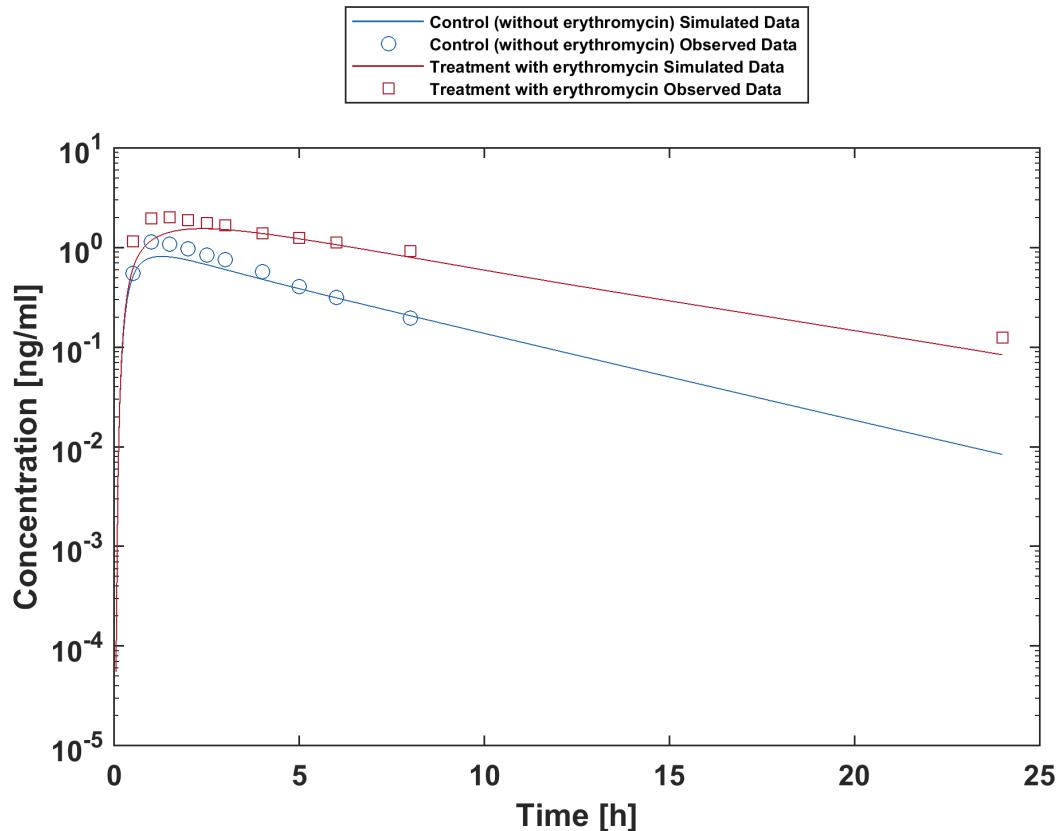


Swart 2002

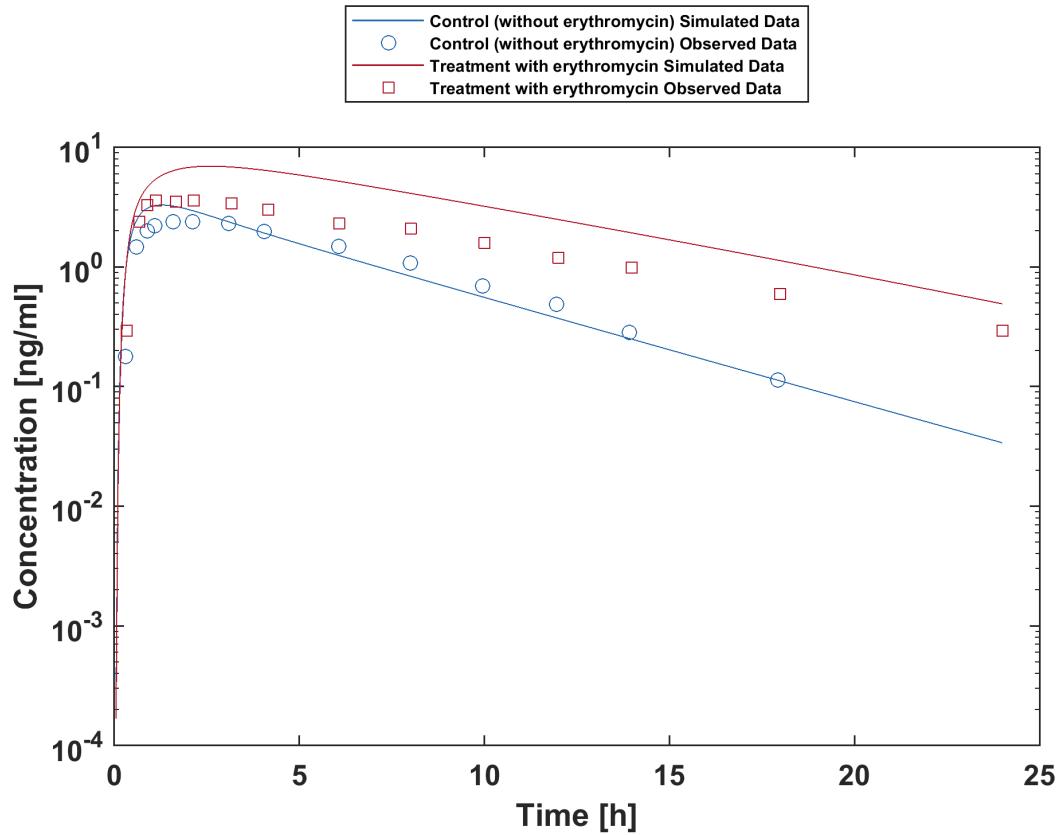


Zimmermann 1996

3.19 Erythromycin - Triazolam DDI

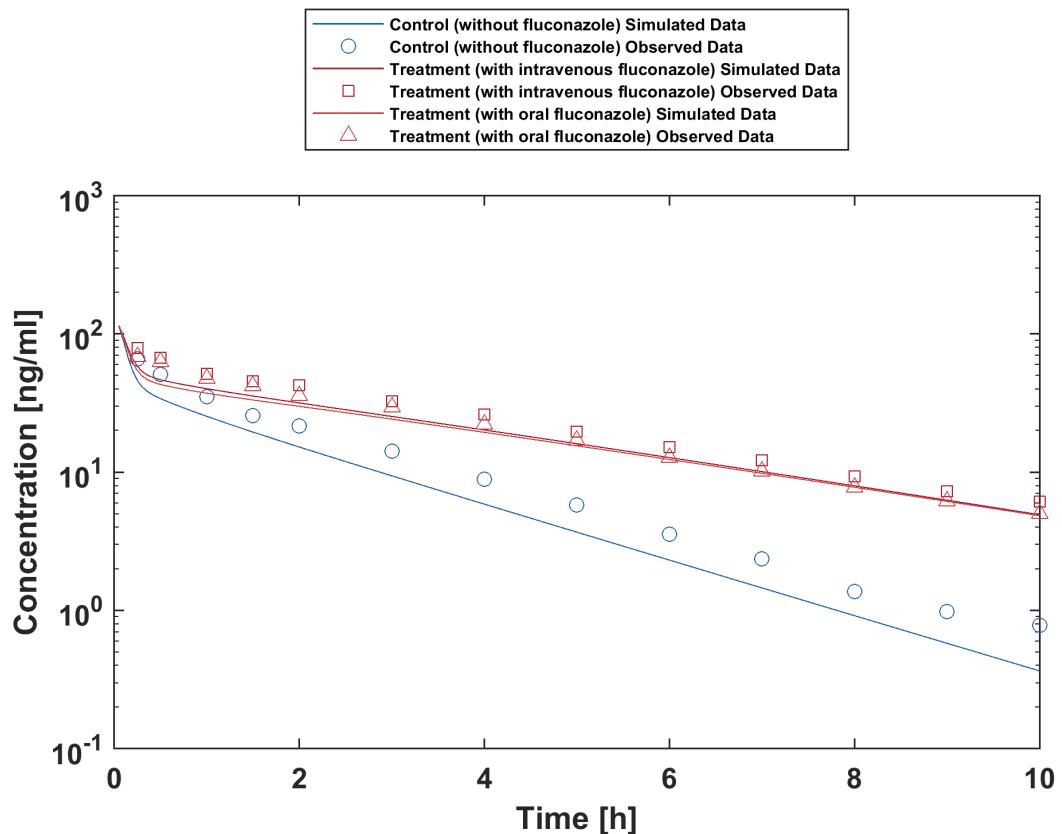


Greenblatt 1998



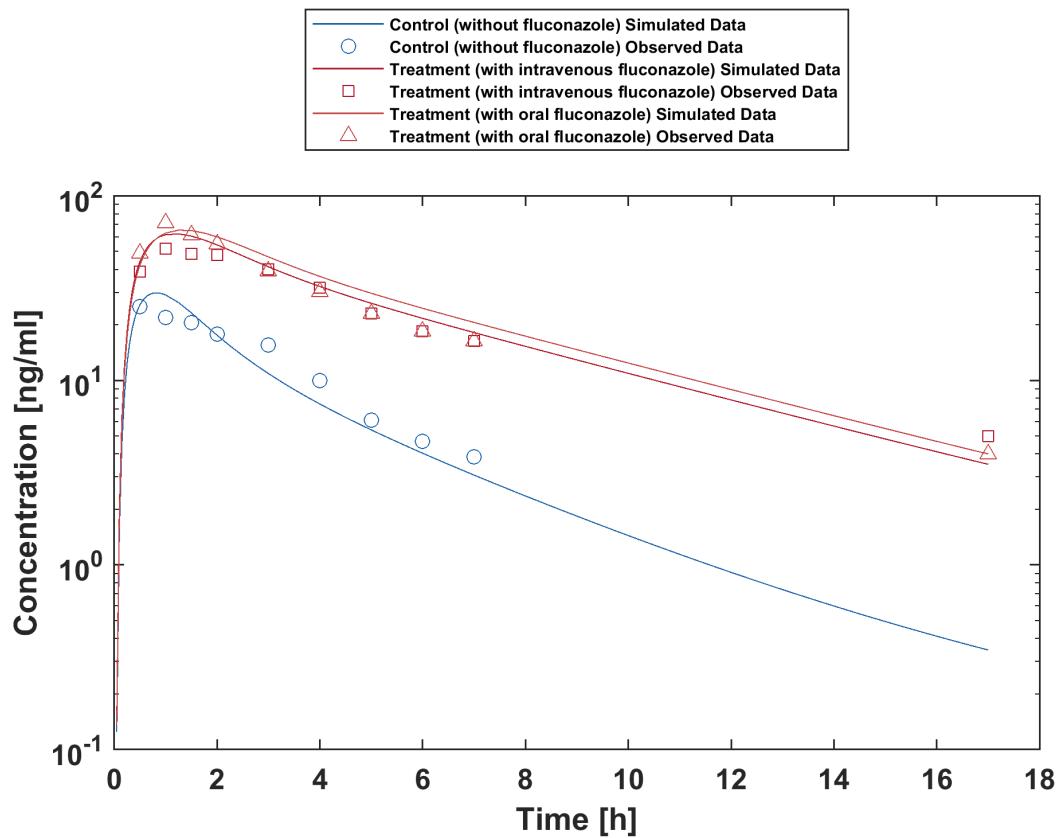
Phillips 1986

3.20 Fluconazole - Alfentanil DDI

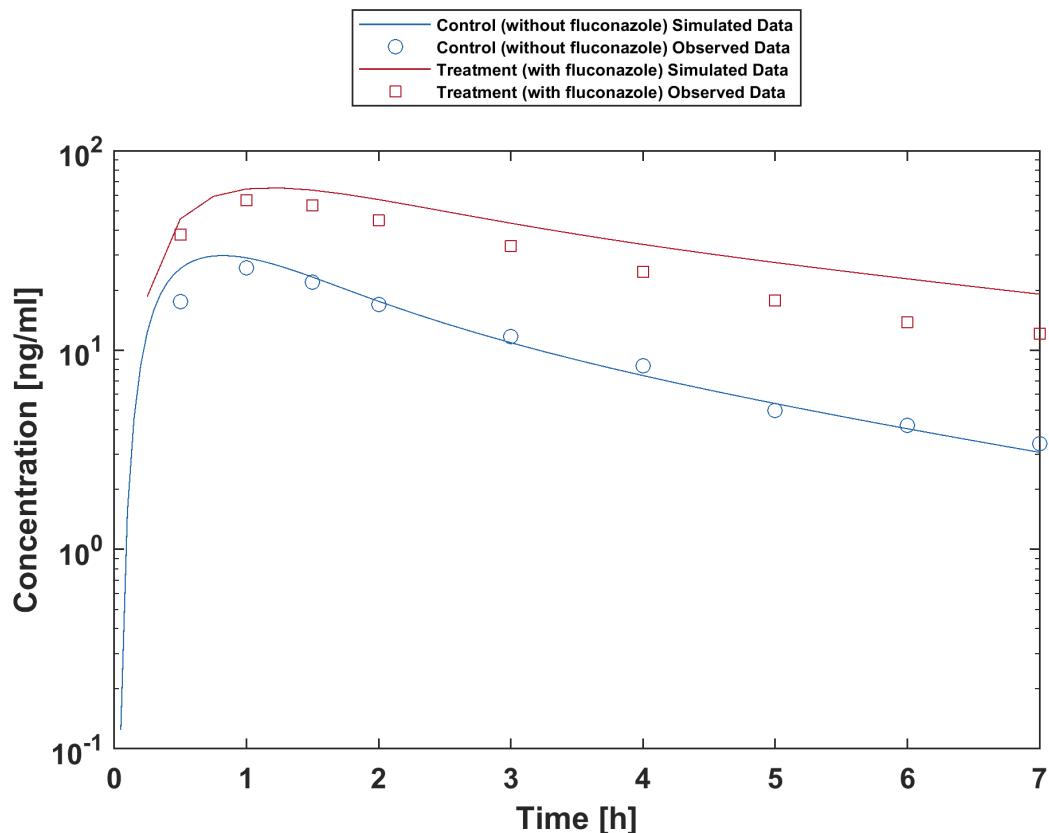


Palkama 1998

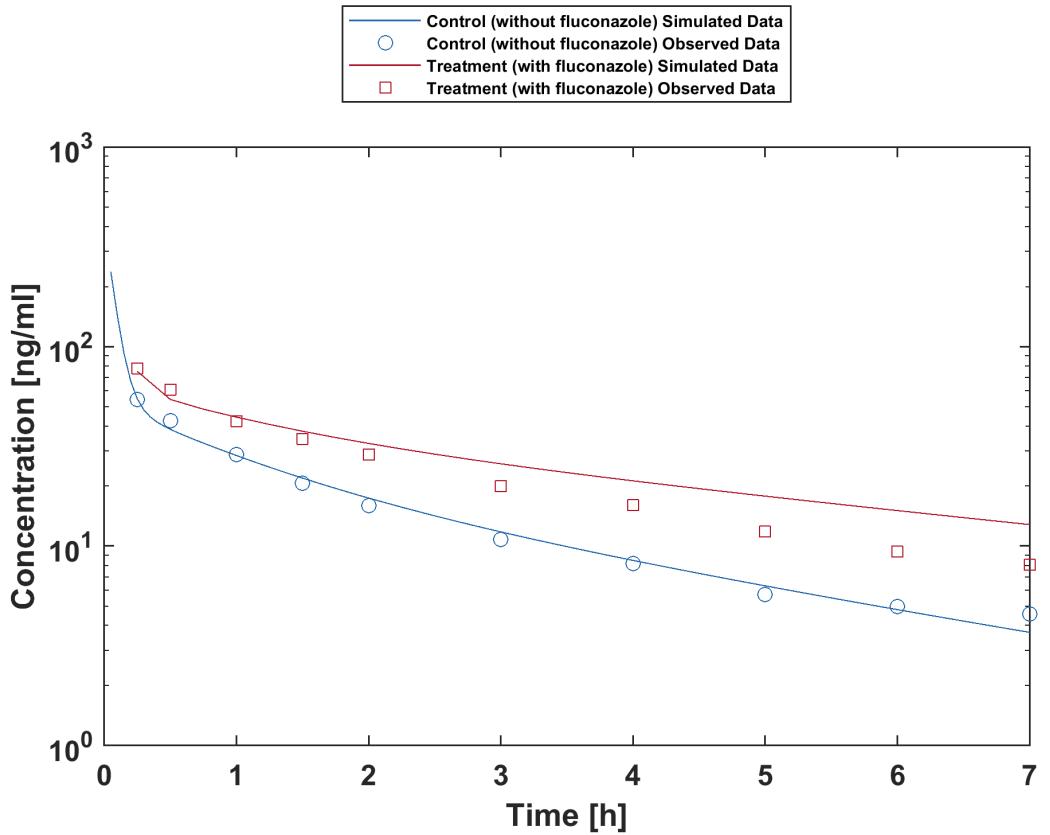
3.21 Fluconazole - Midazolam DDI



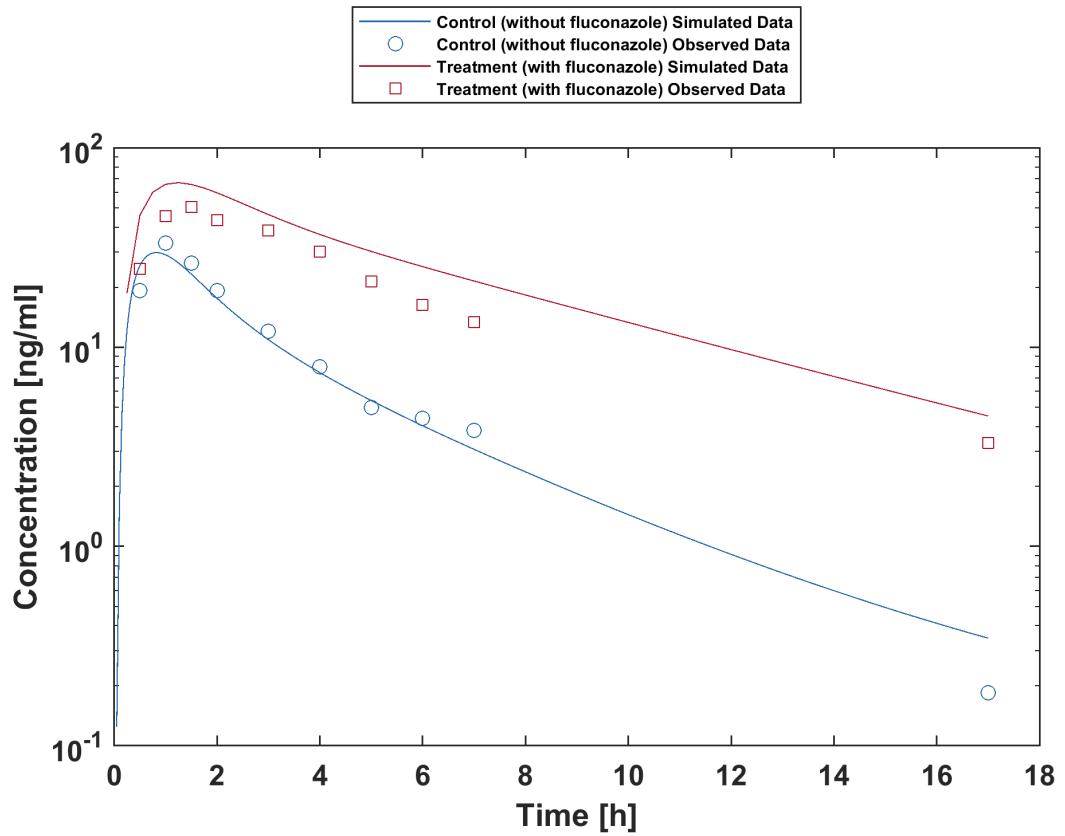
Ahonen 1997



Olkola 1996 Day 1

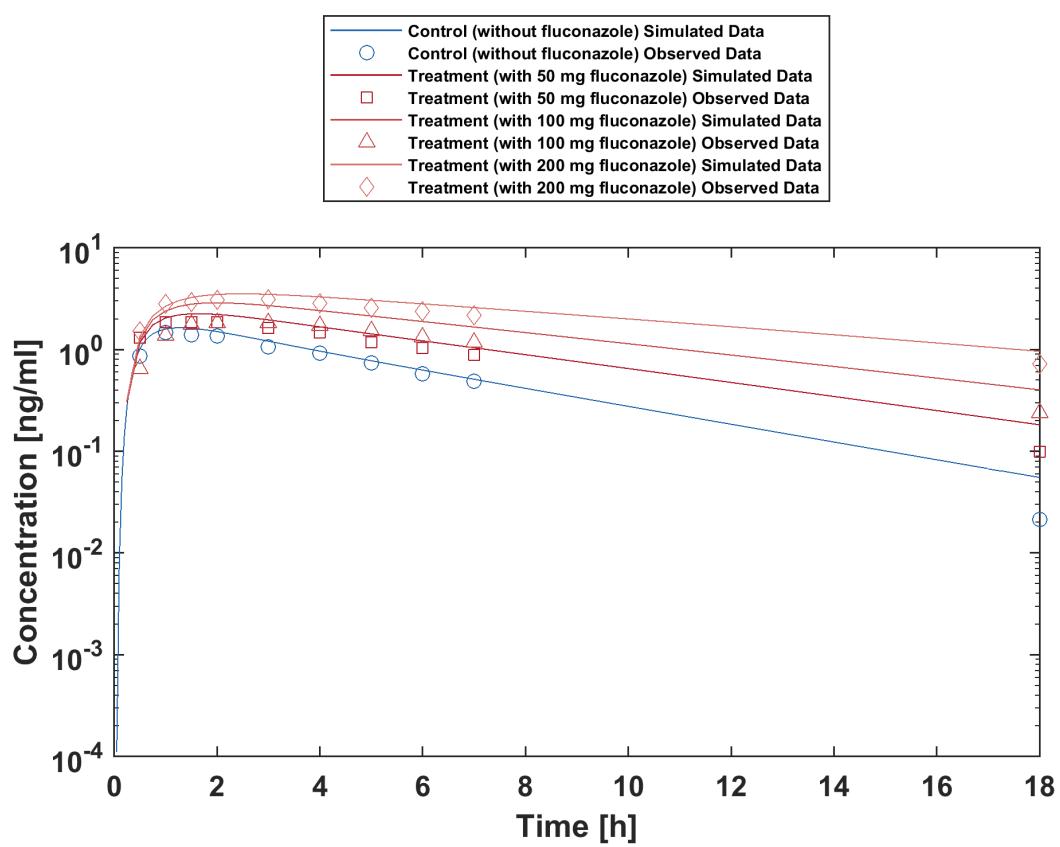


Olkola 1996 Day 4



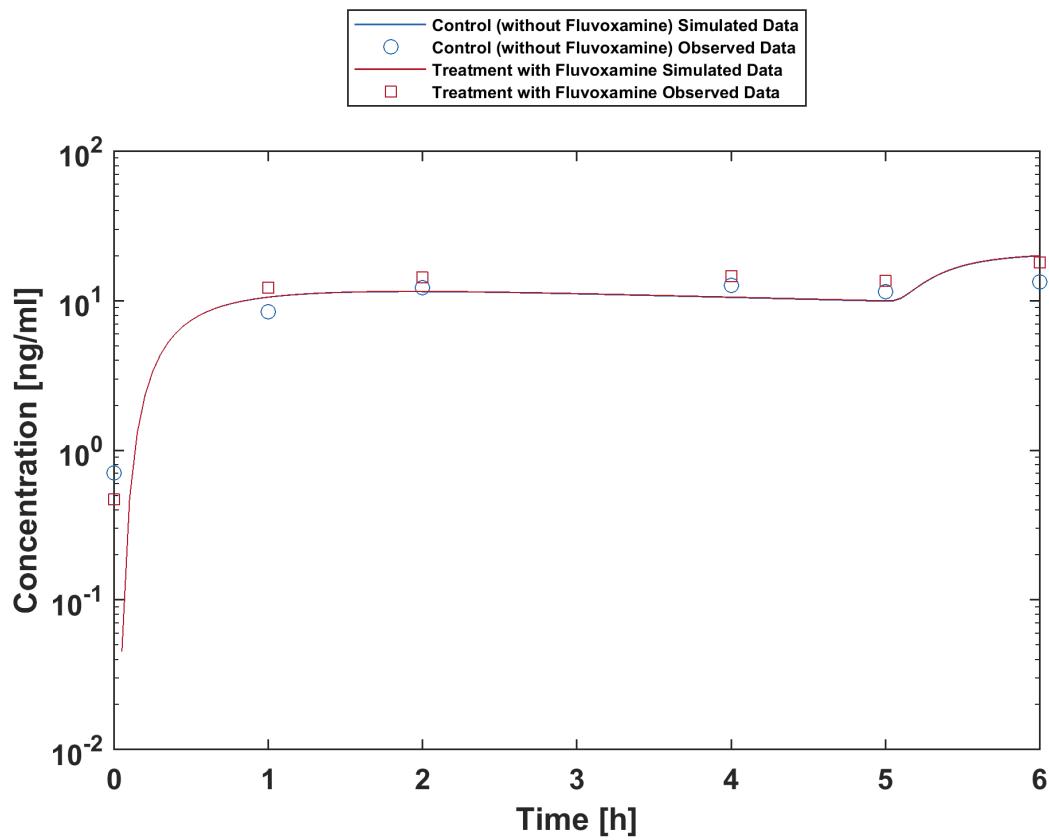
Olkola 1996 Day 6

3.22 Fluconazole - Triazolam DDI

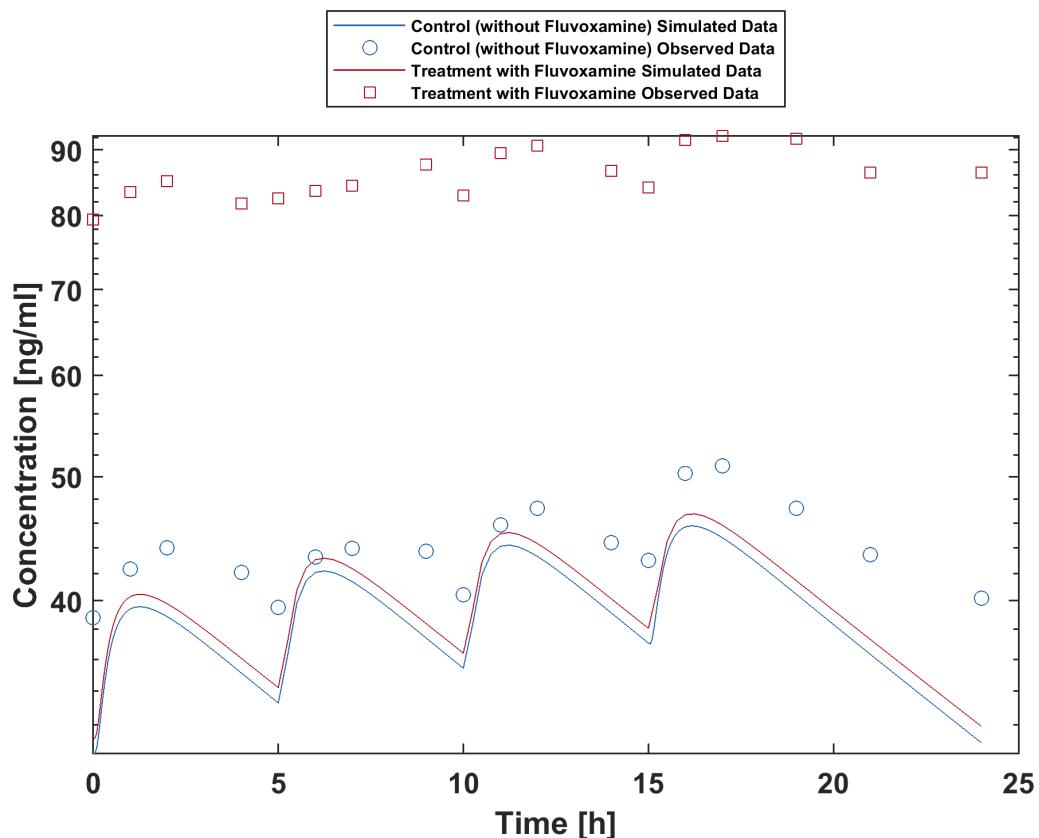


Varhe 1996c

3.23 Fluvoxamine - Alprazolam DDI

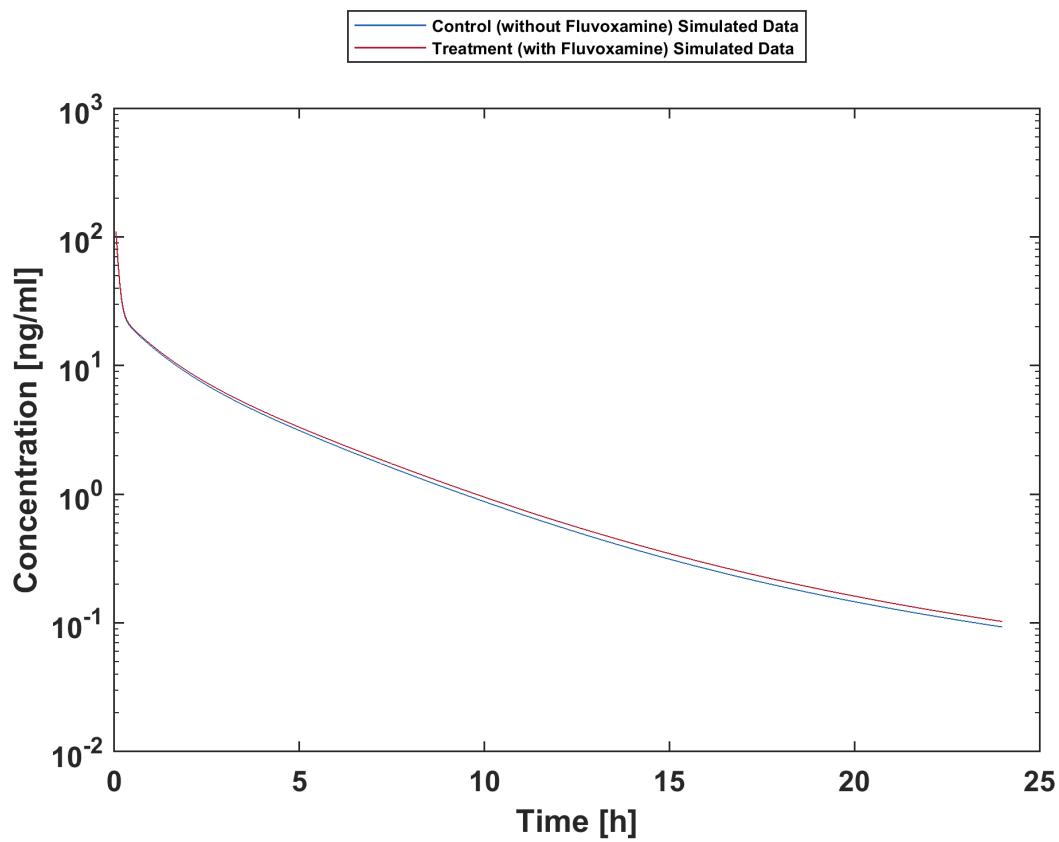


Fleishaker 1994 (Day 1, first dose)

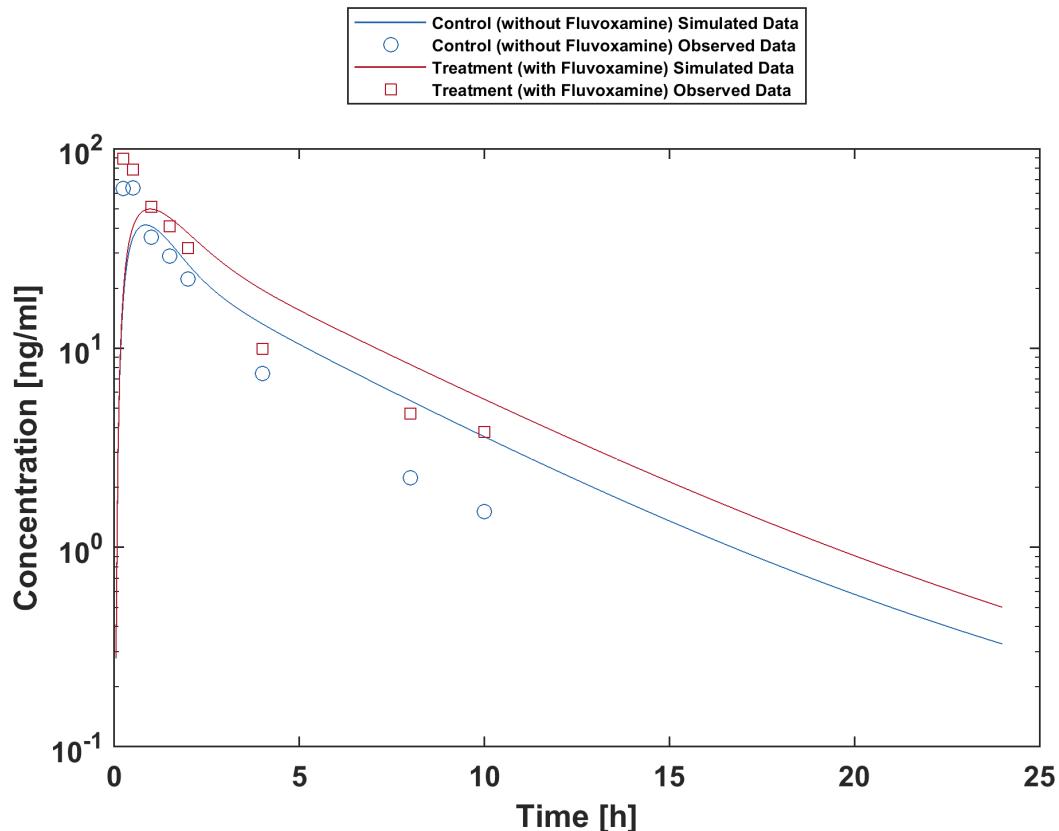


Fleishaker 1994 (Day 10)

3.24 Fluvoxamine - Midazolam DDI

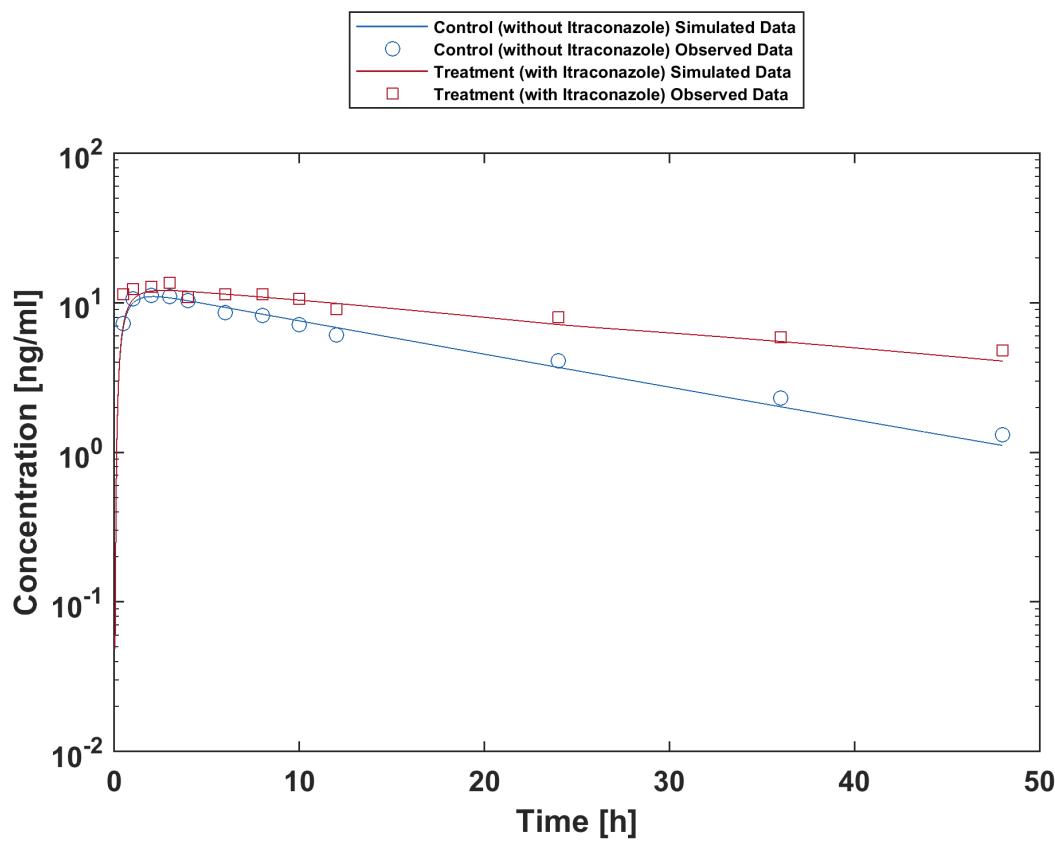


Kashuba 1998



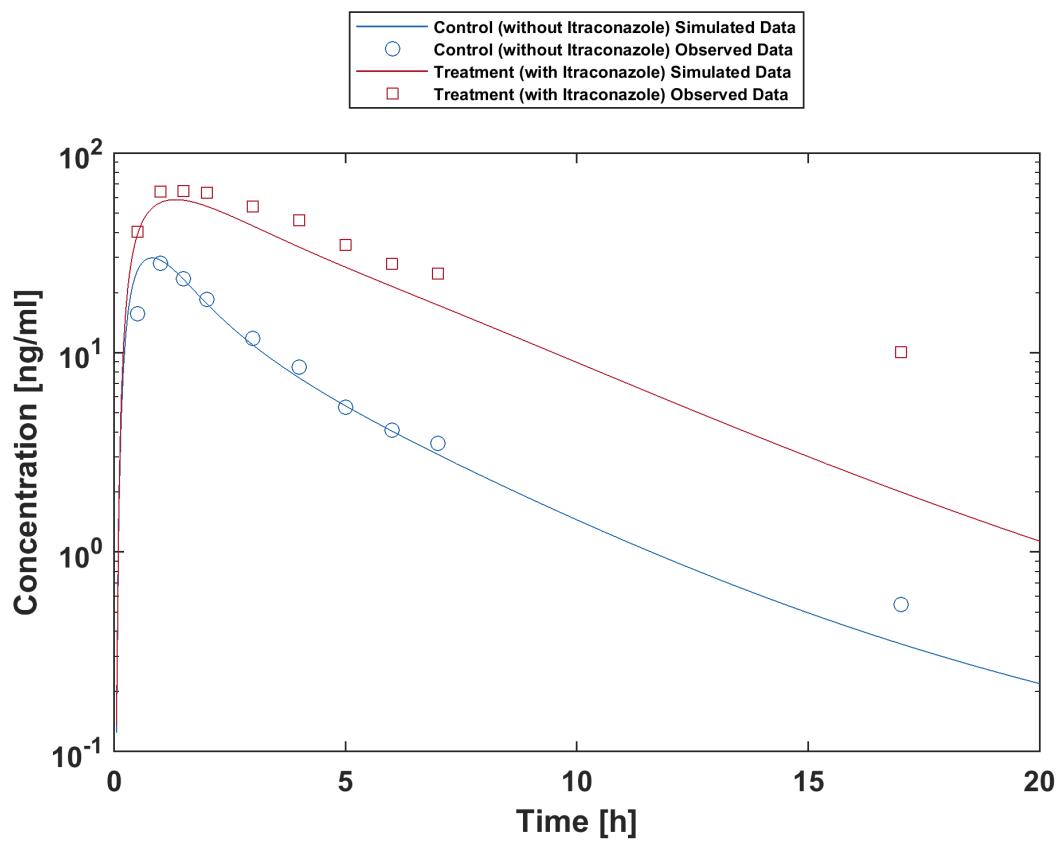
Lam 2003

3.25 Itraconazole - Alprazolam DDI

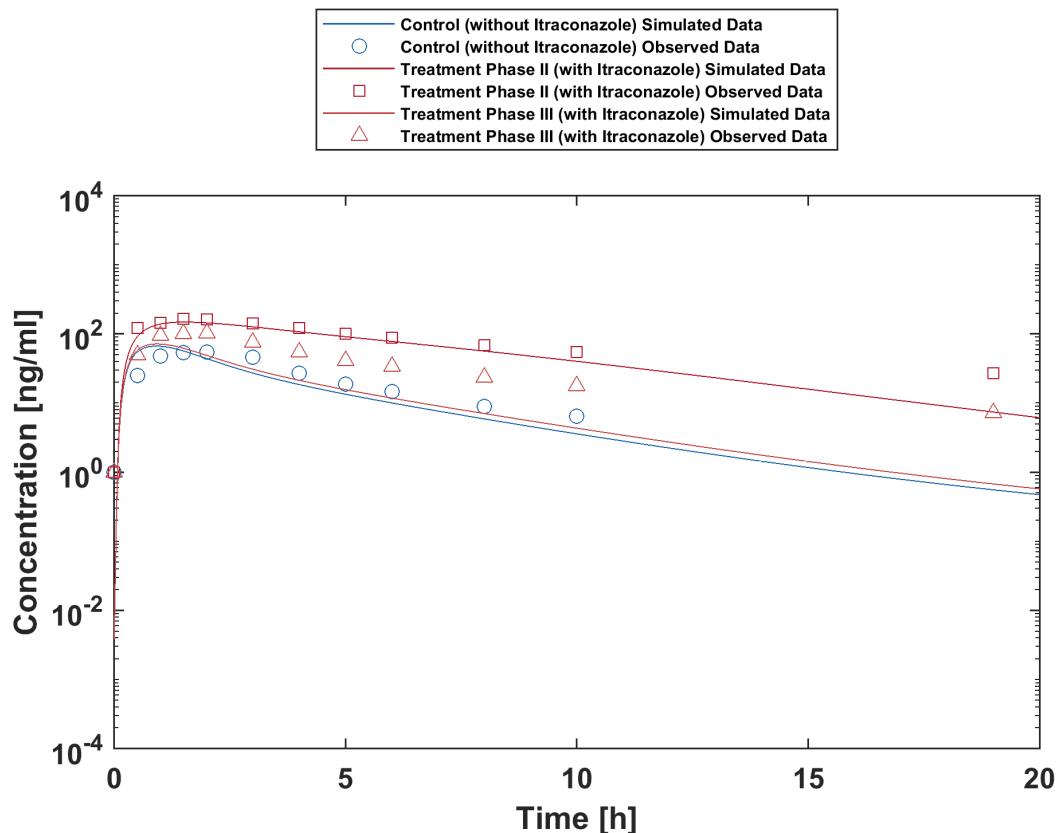


Yasui 1998

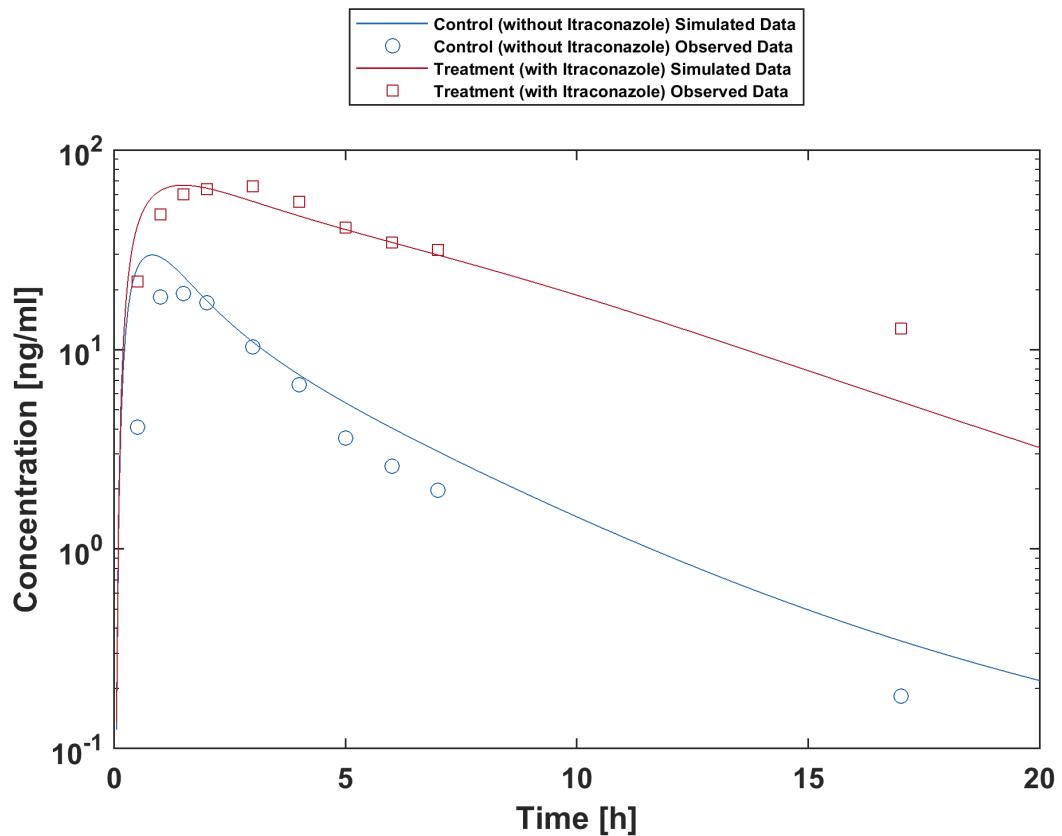
3.26 Itraconazole - Midazolam DDI



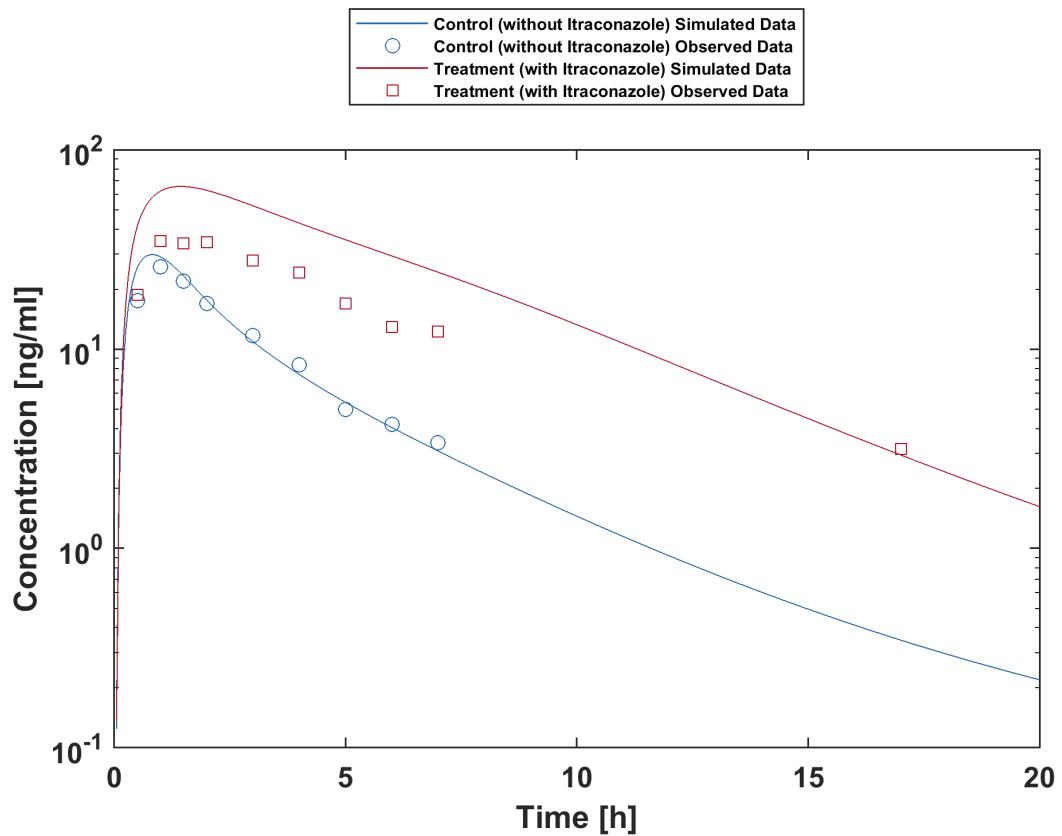
Ahonen 1995



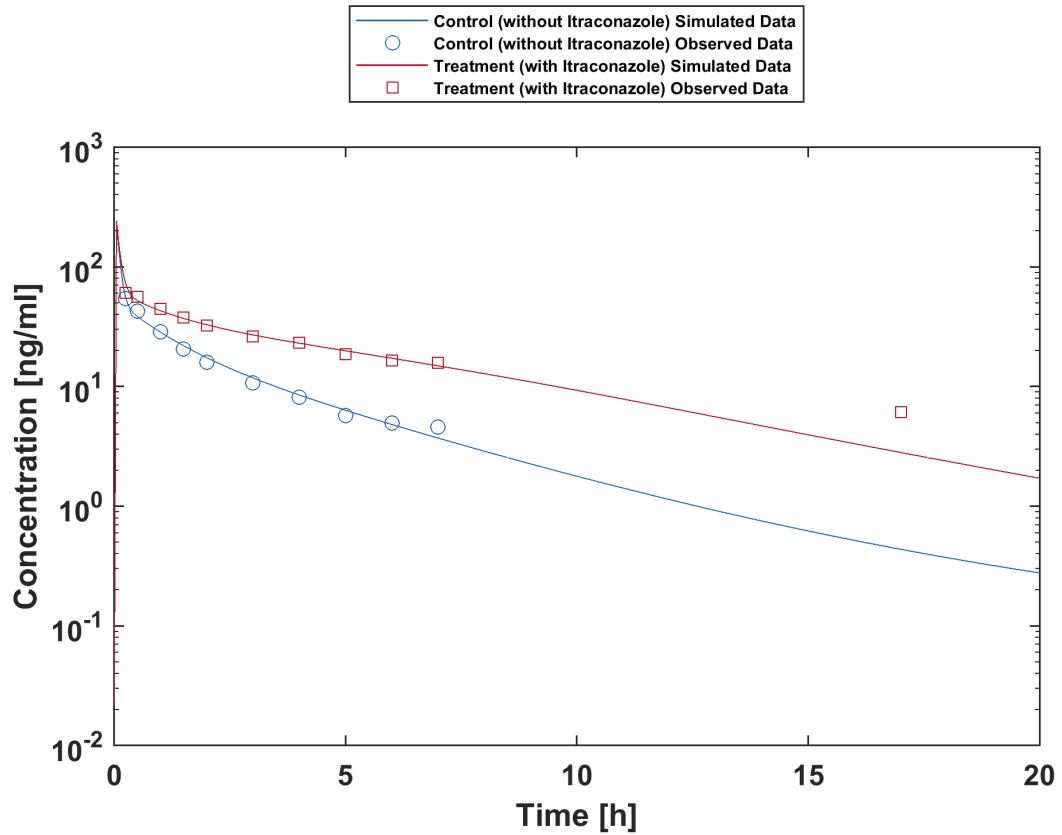
Backman 1998



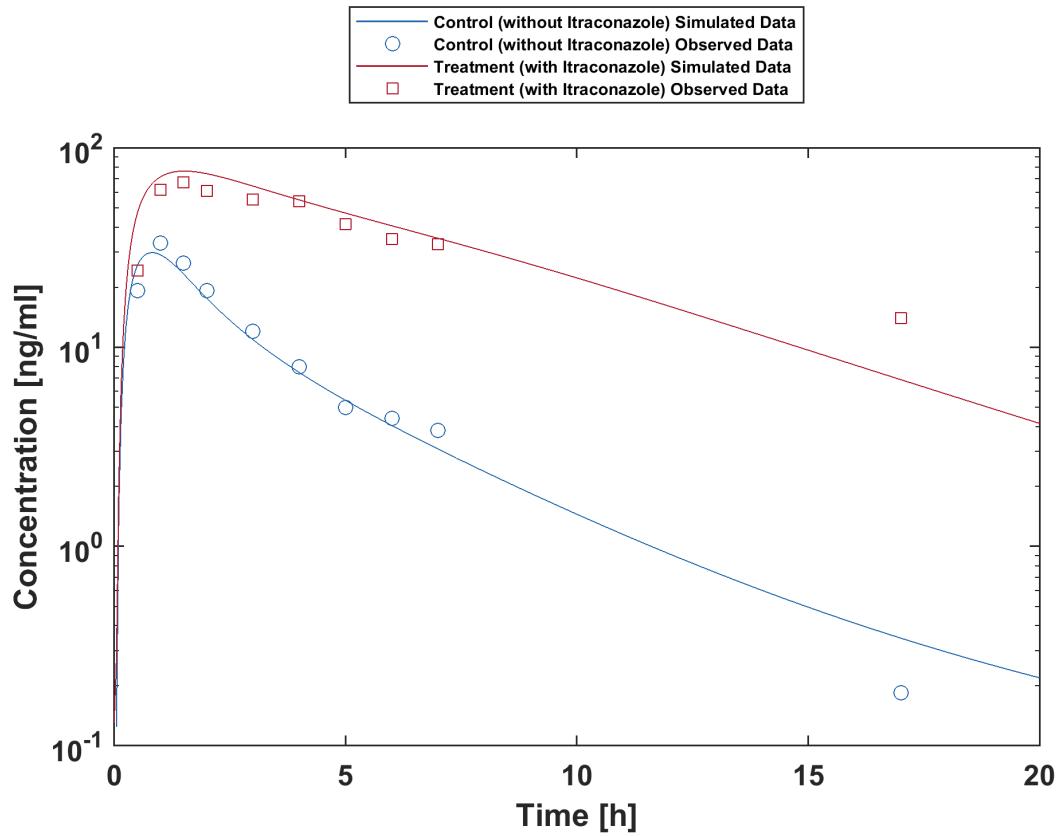
Olkola 1994



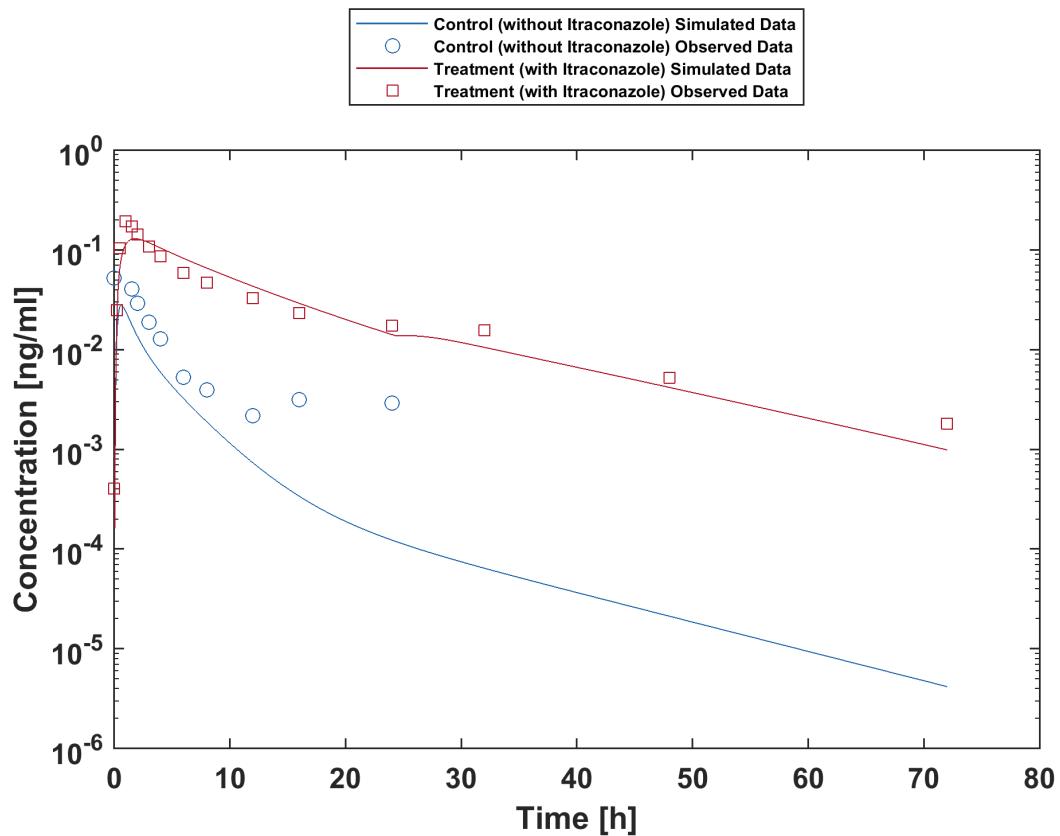
Olkola 1996 (day 1 po)



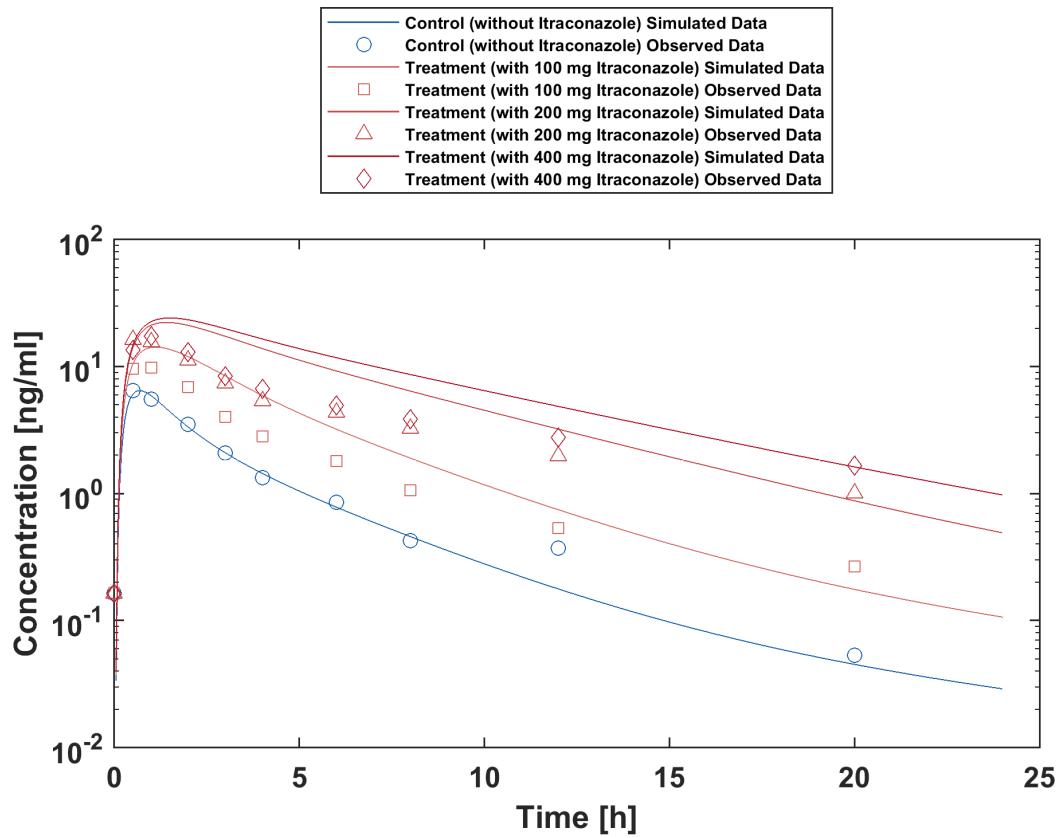
Olkola 1996 (day 4 iv)



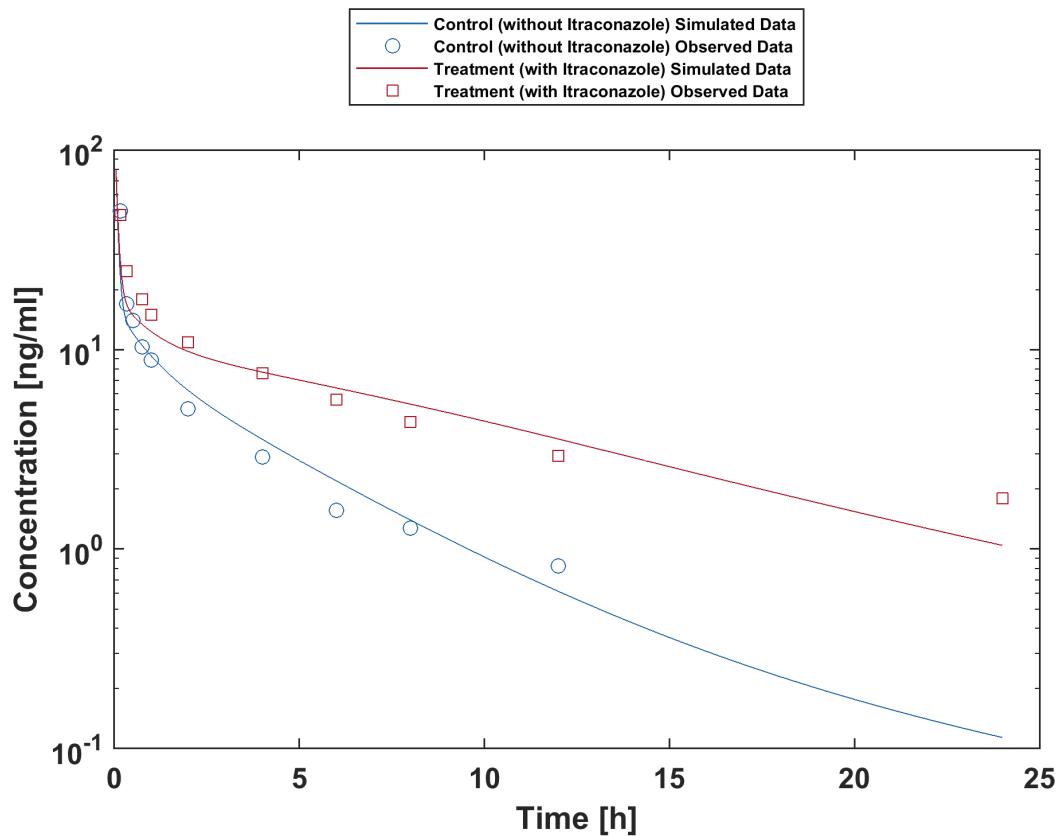
Olkola 1996 (day 6 po)



Pruksaritanont 2017

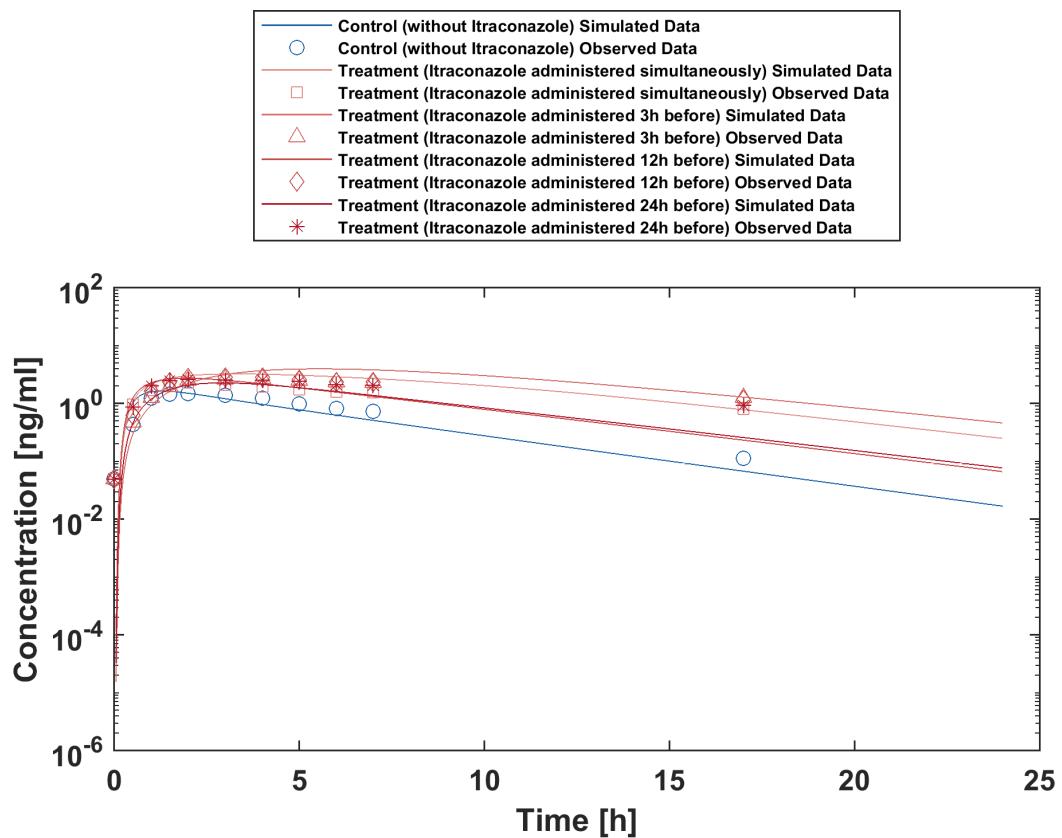


Templeton 2010

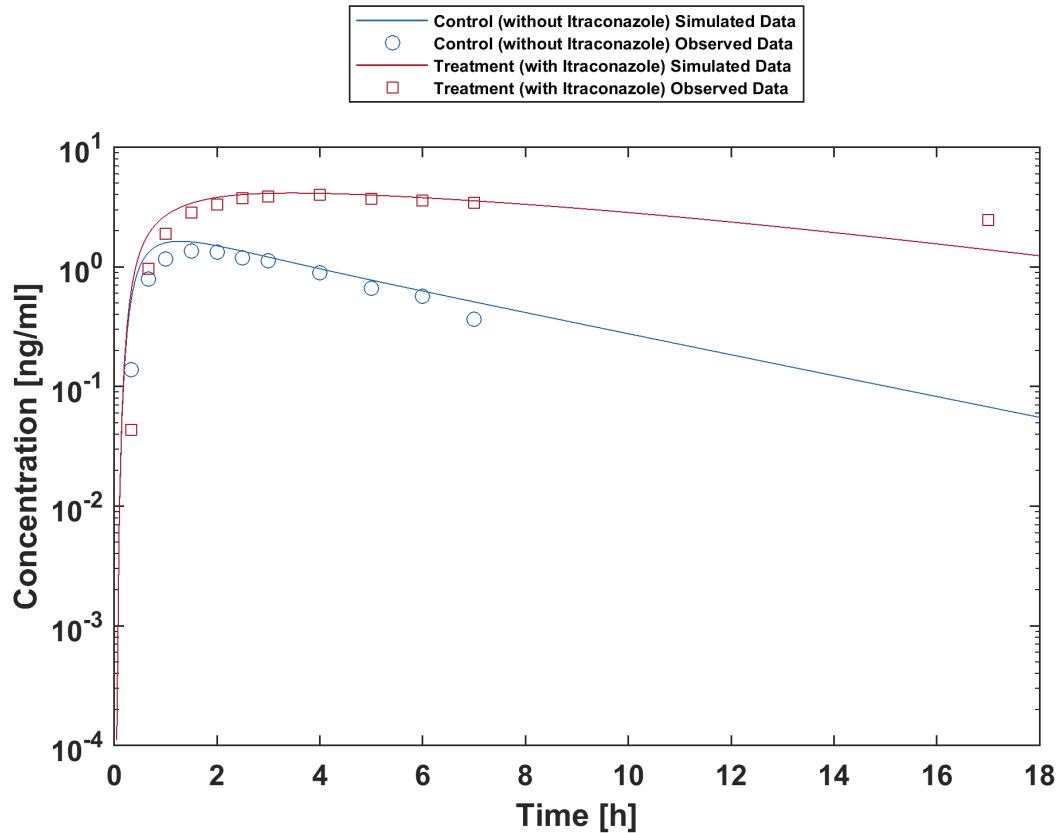


Yu 2004 (CYP3A5*3/*3)

3.27 Itraconazole - Triazolam DDI

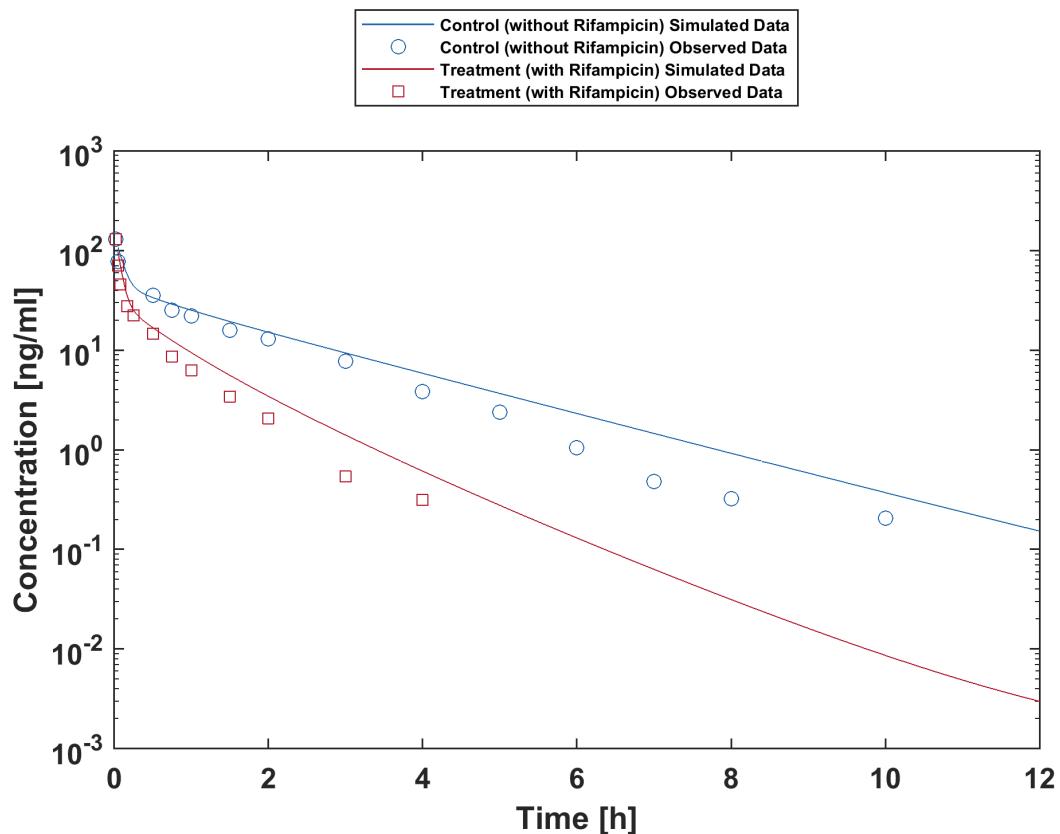


Neuvonen 1996

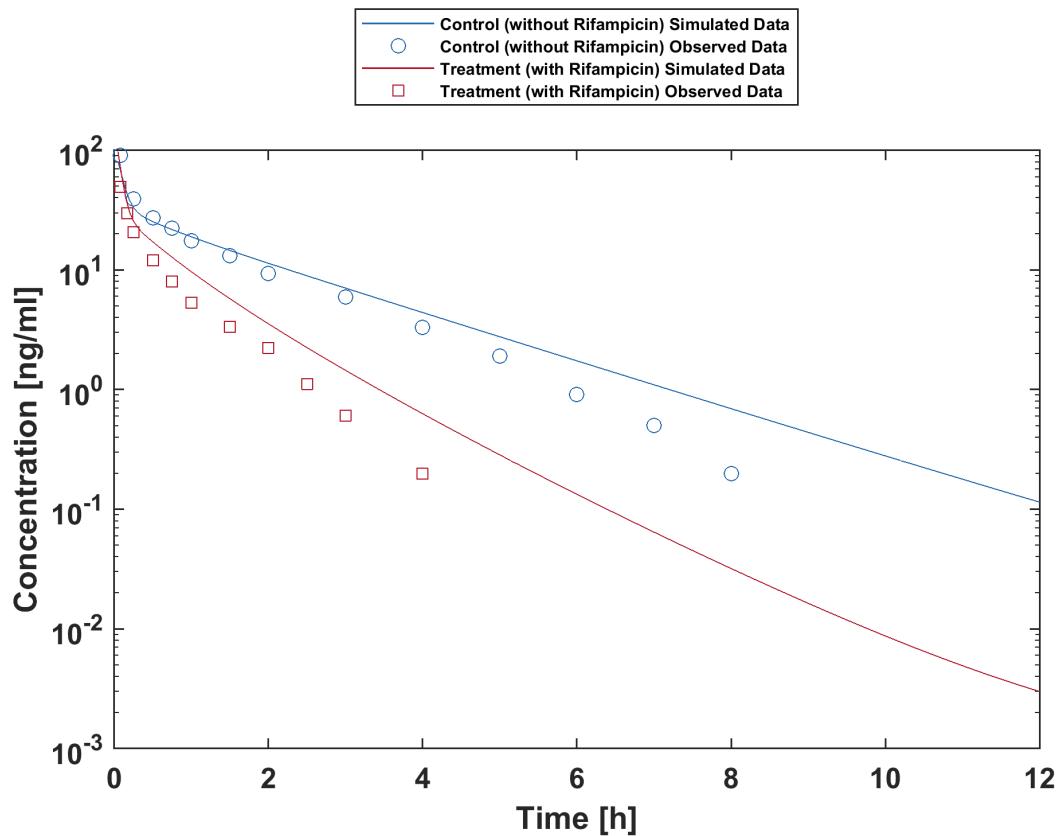


Varhe 1994

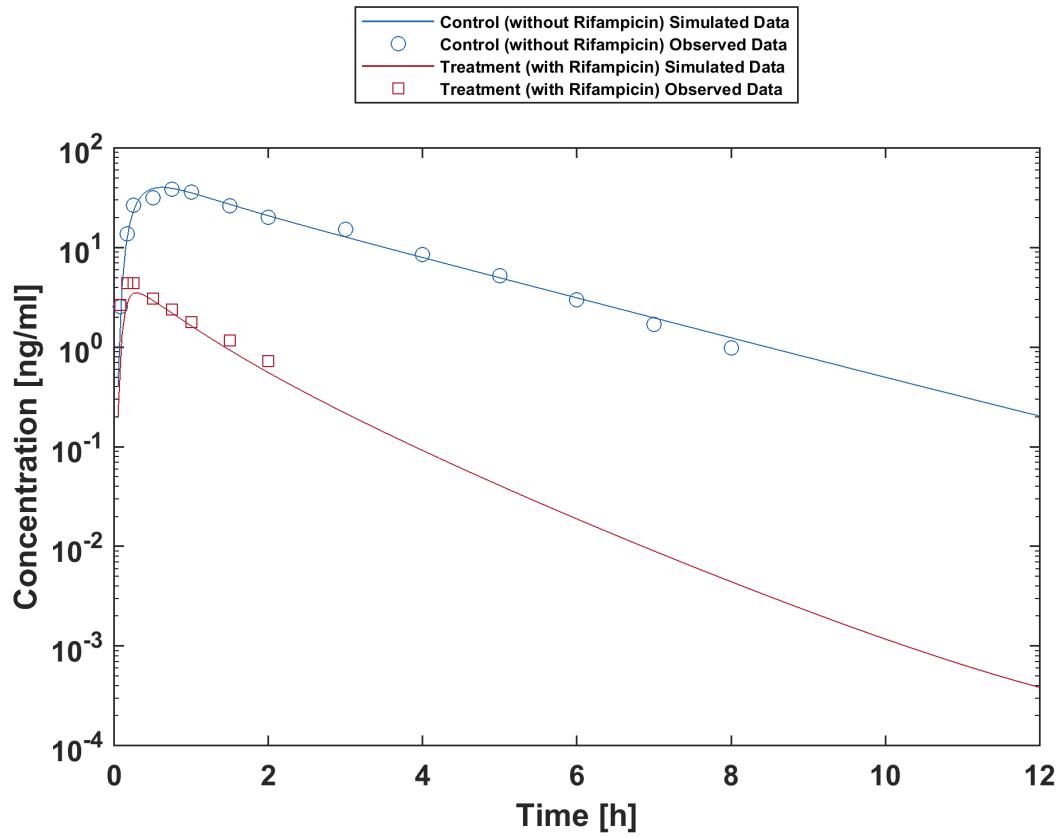
3.28 Rifampicin - Alfentanil DDI



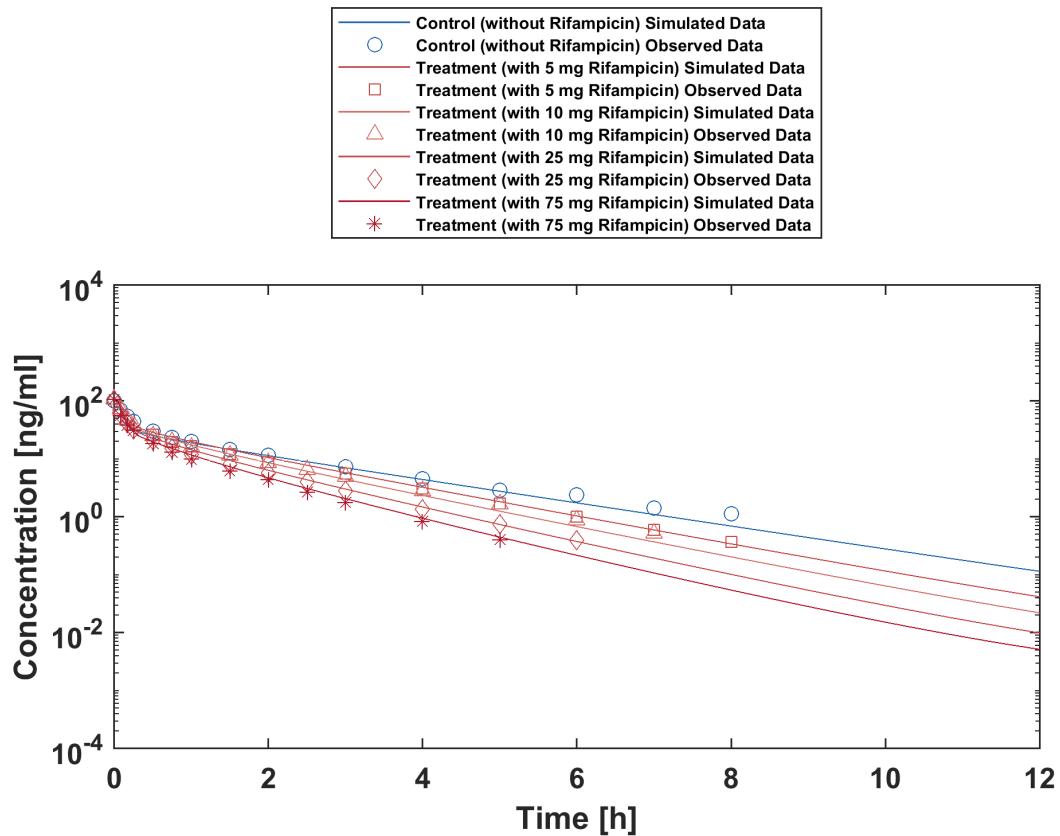
Kharasch 1997



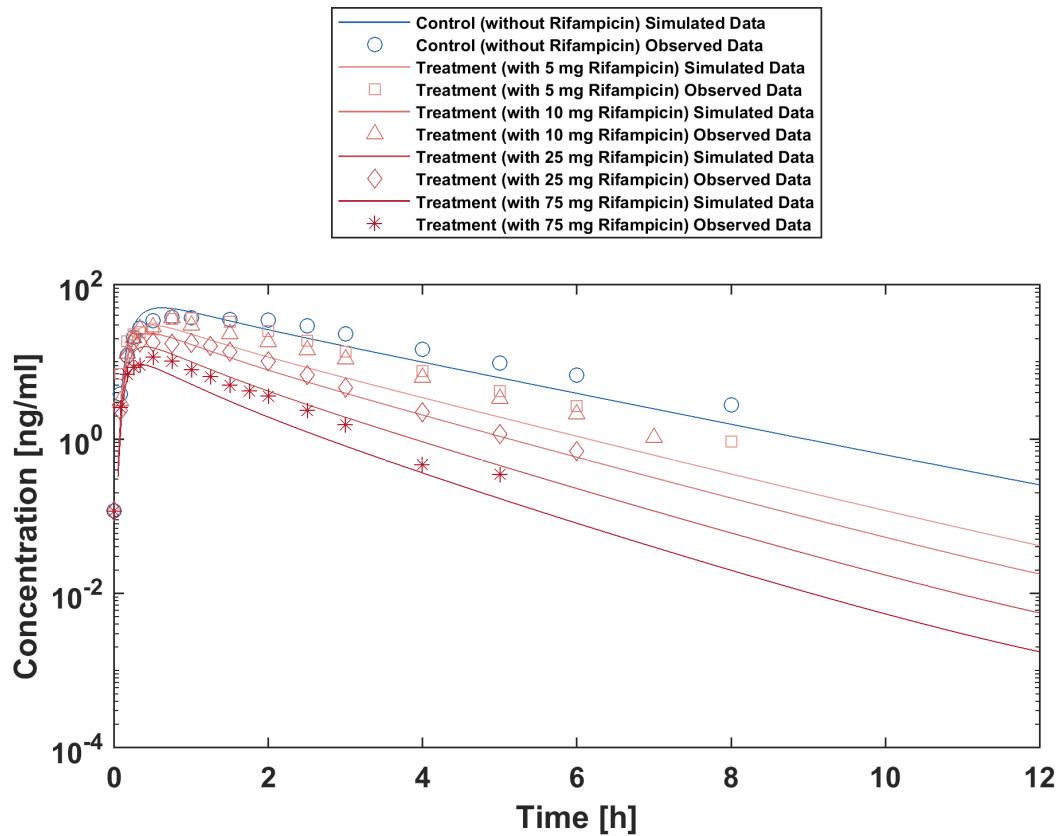
Kharasch 2004 (iv)



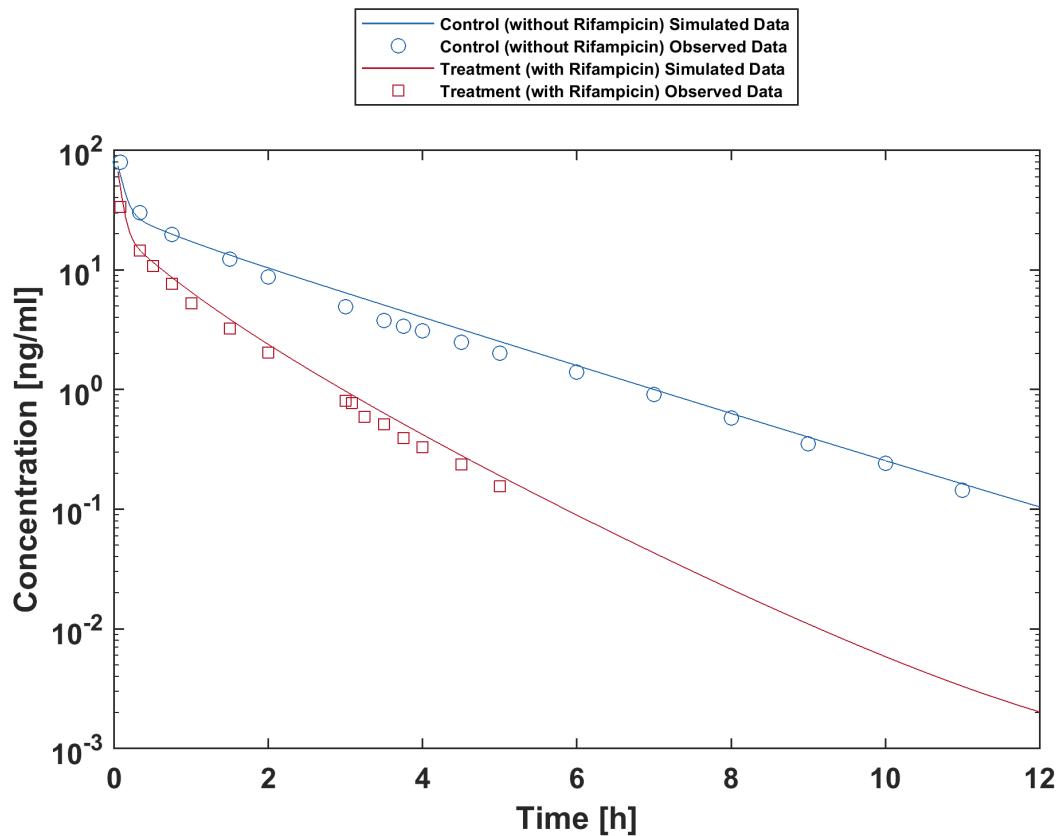
Kharasch 2004 (po)



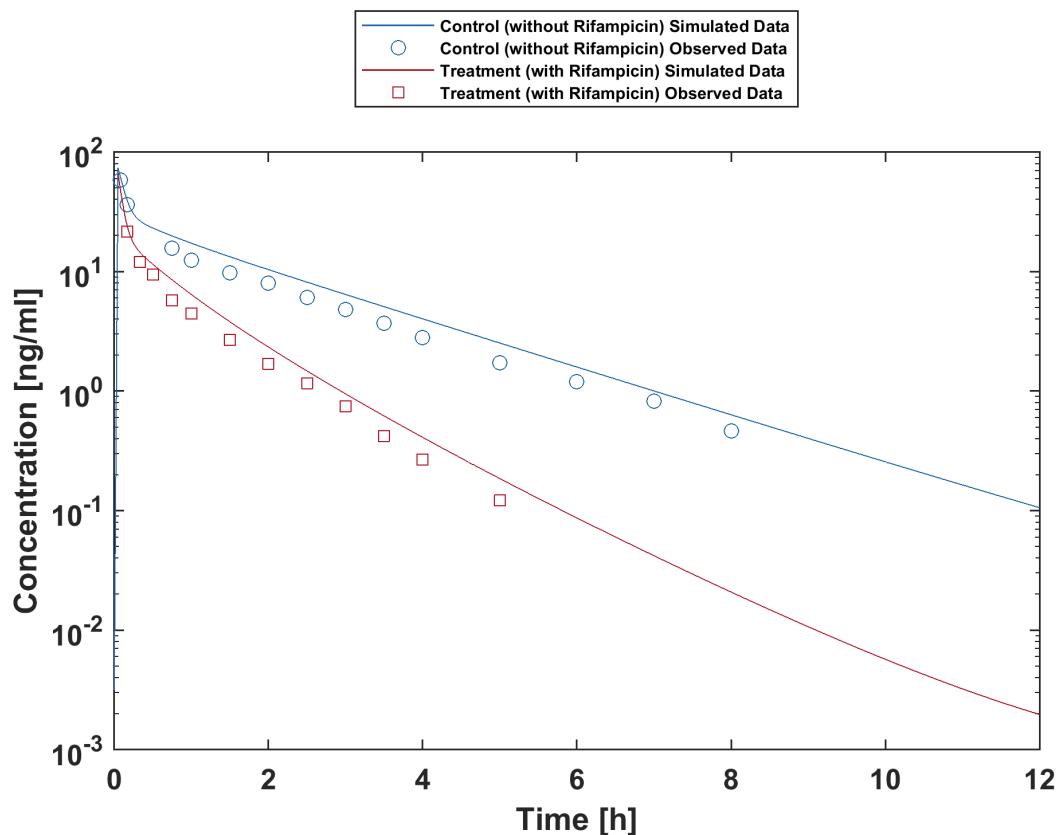
Kharasch 2011 (iv)



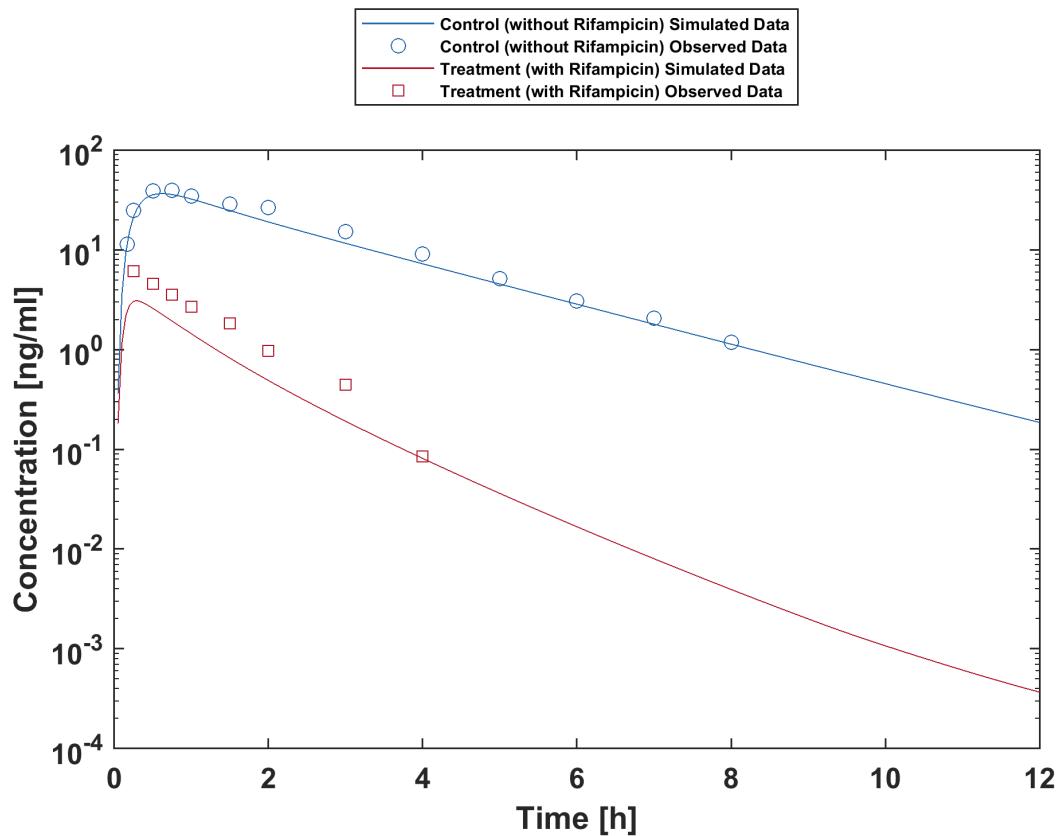
Kharasch 2011 (po)



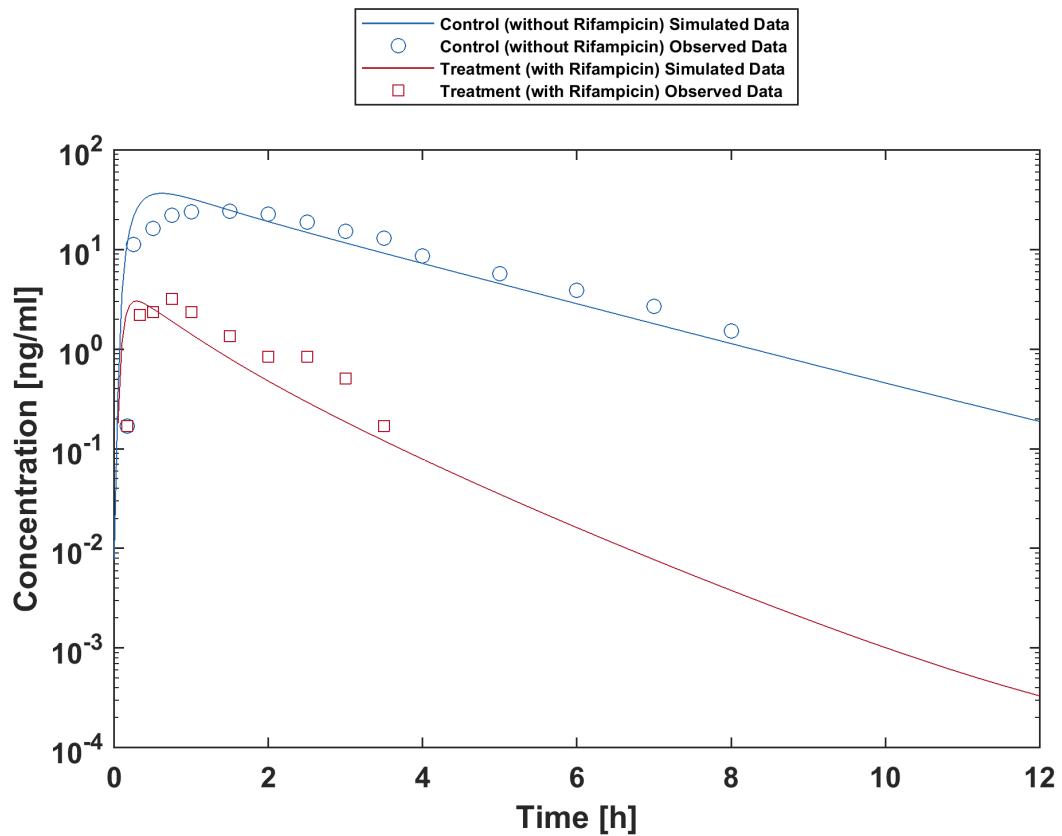
Kharasch 2011b (iv during sequential administration of iv unlabeled alfentanil and oral deuterated alfentanil)



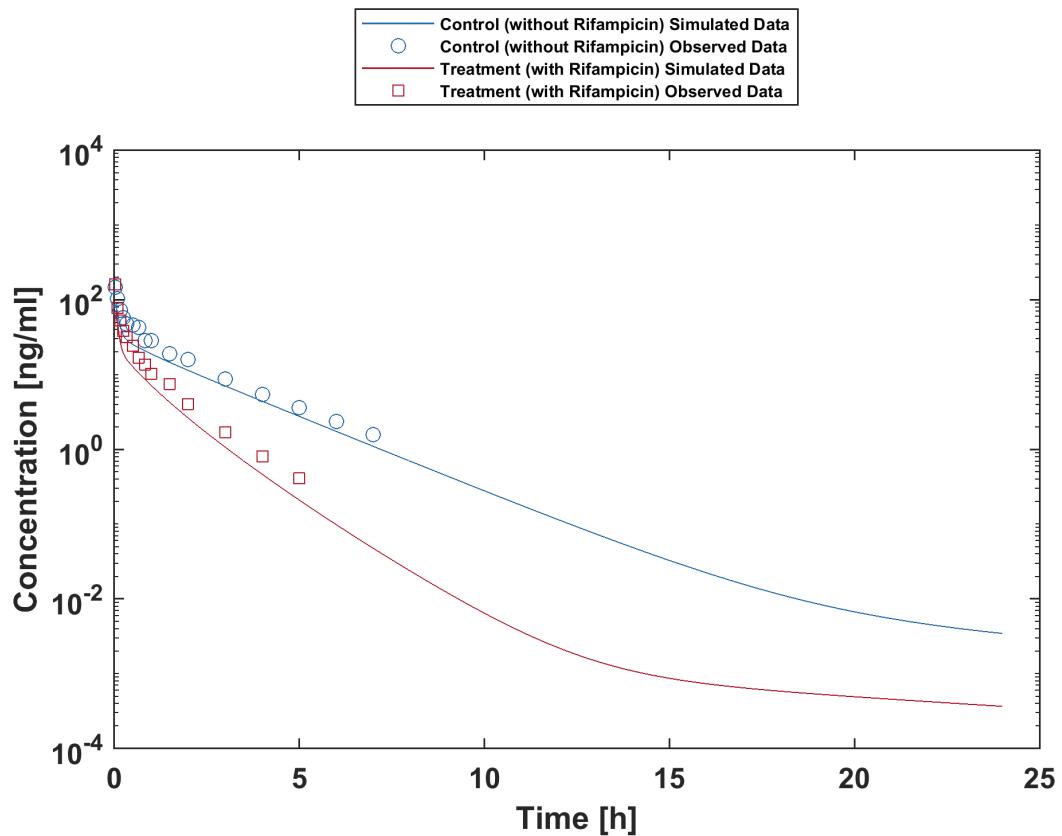
Kharasch 2011b (iv during simultaneous administration of iv unlabeled alfentanil and oral deuterated alfentanil)



Kharasch 2011b (po during sequential administration of iv unlabeled alfentanil and oral deuterated alfentanil)

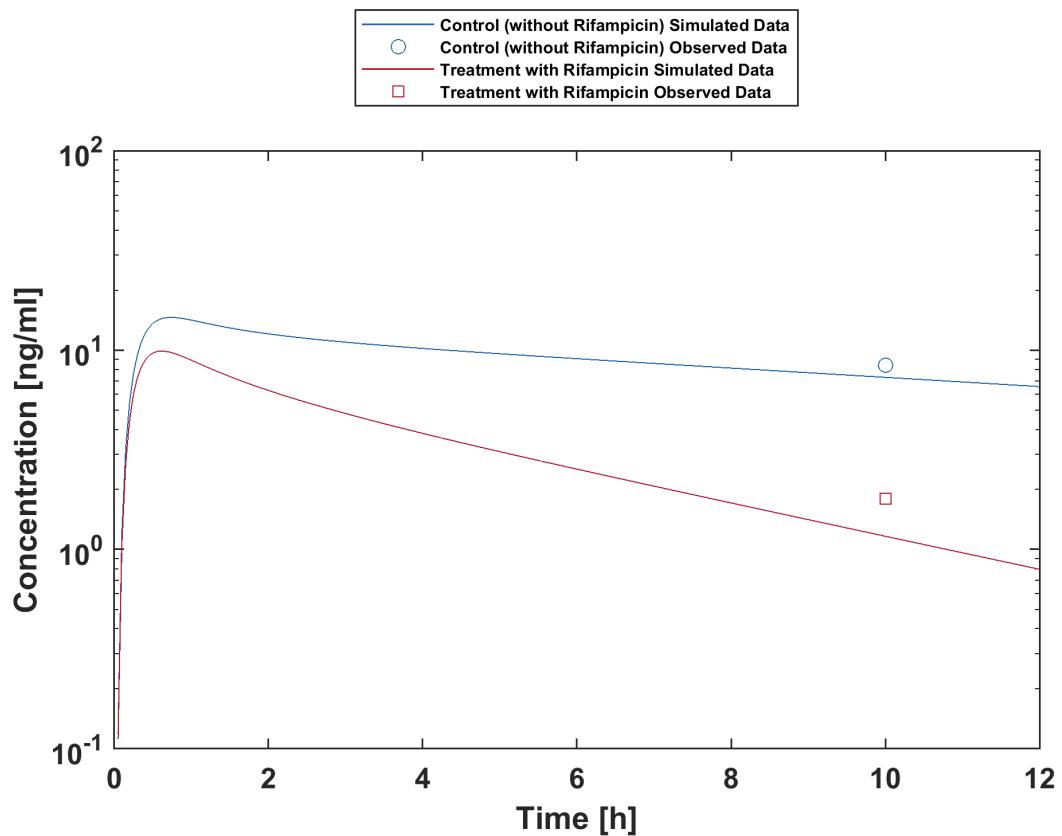


Kharasch 2011b (po during simultaneous administration of iv unlabeled alfentanil and oral deuterated alfentanil)

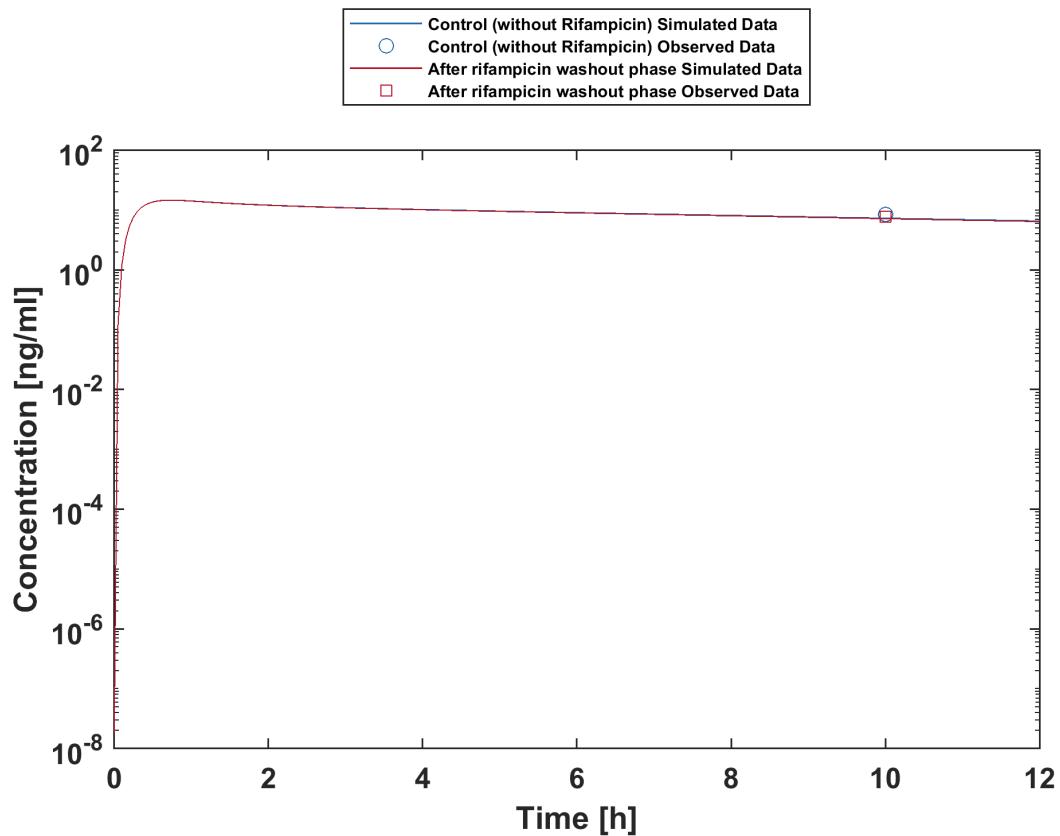


Phimmasone 2001

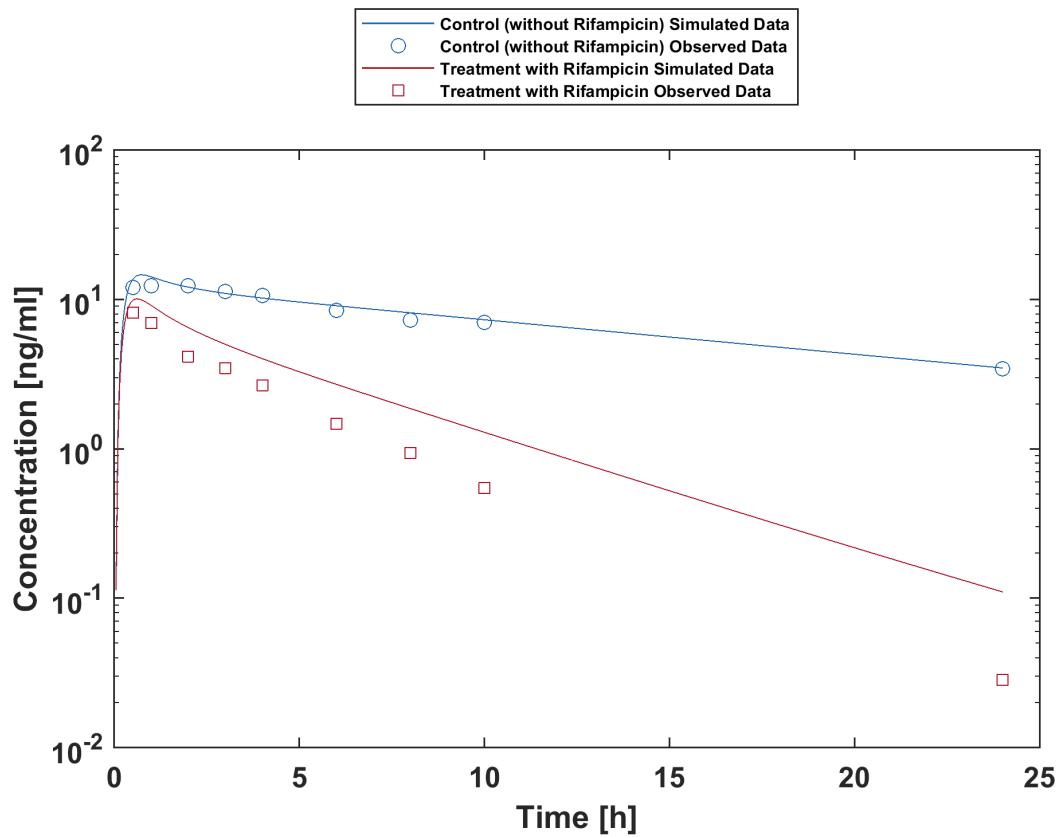
3.29 Rifampicin - Alprazolam DDI



Gashaw 2003 (Day 7)

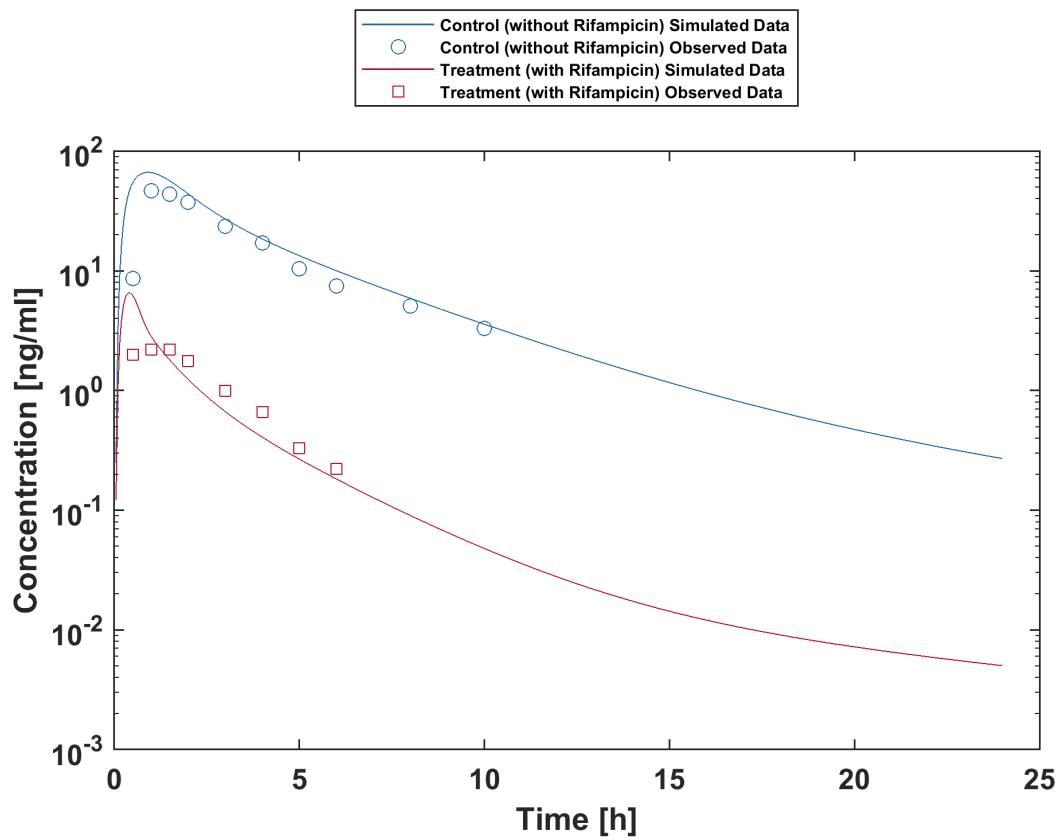


Gashaw 2003 (after washout phase)

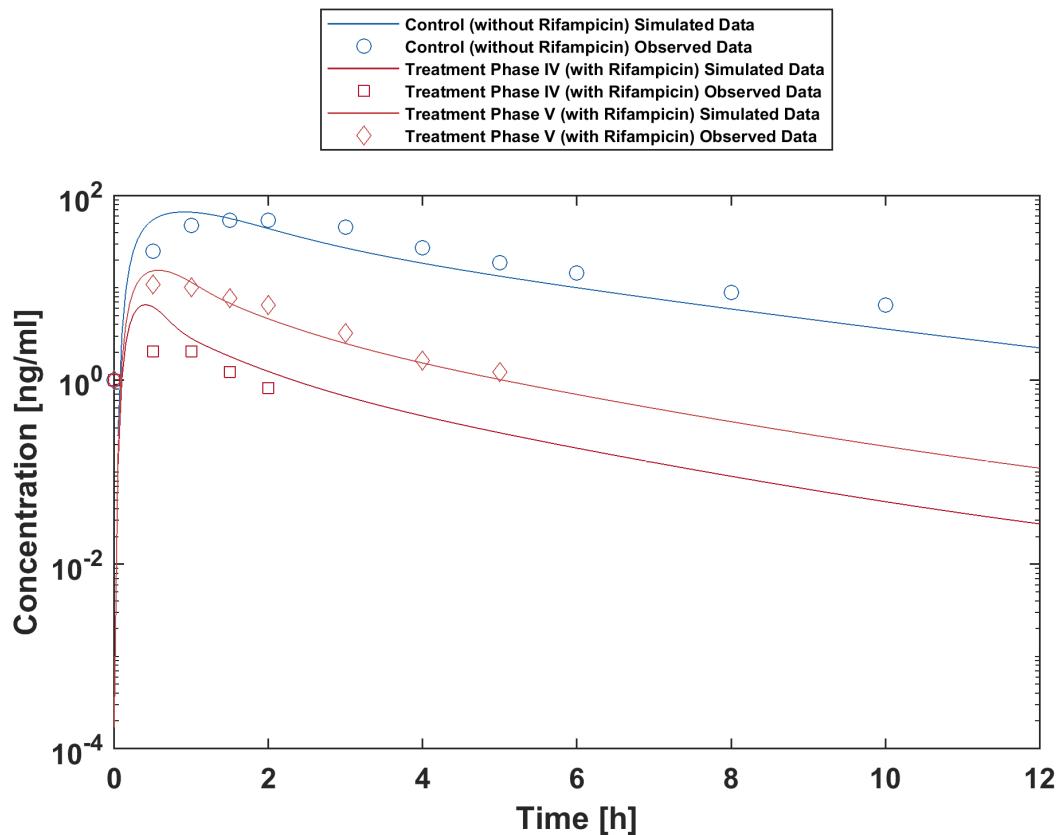


Schmider 1999

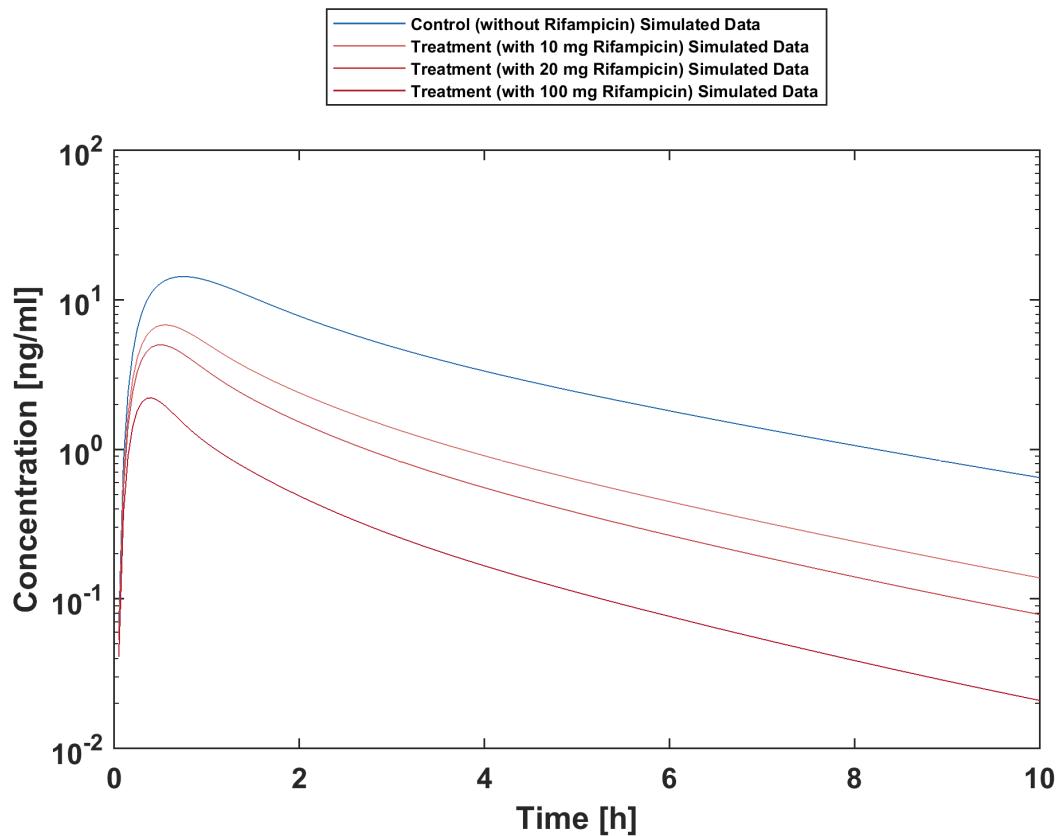
3.30 Rifampicin - Midazolam DDI



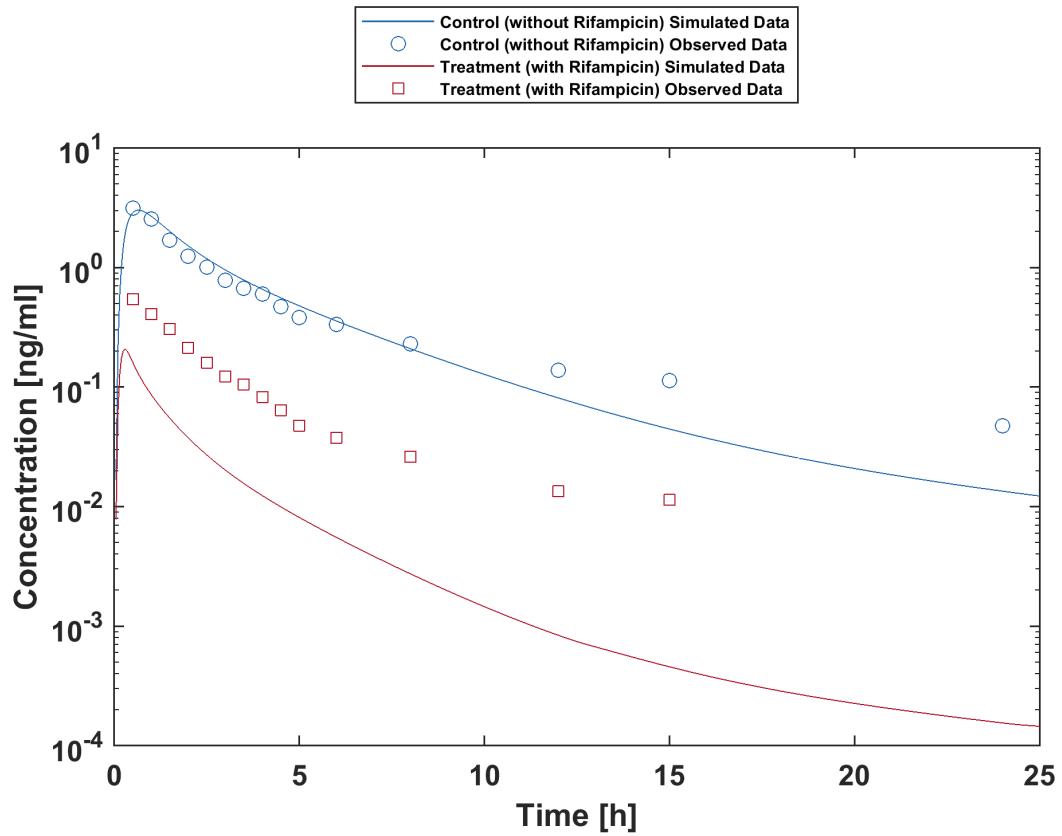
Backman 1996



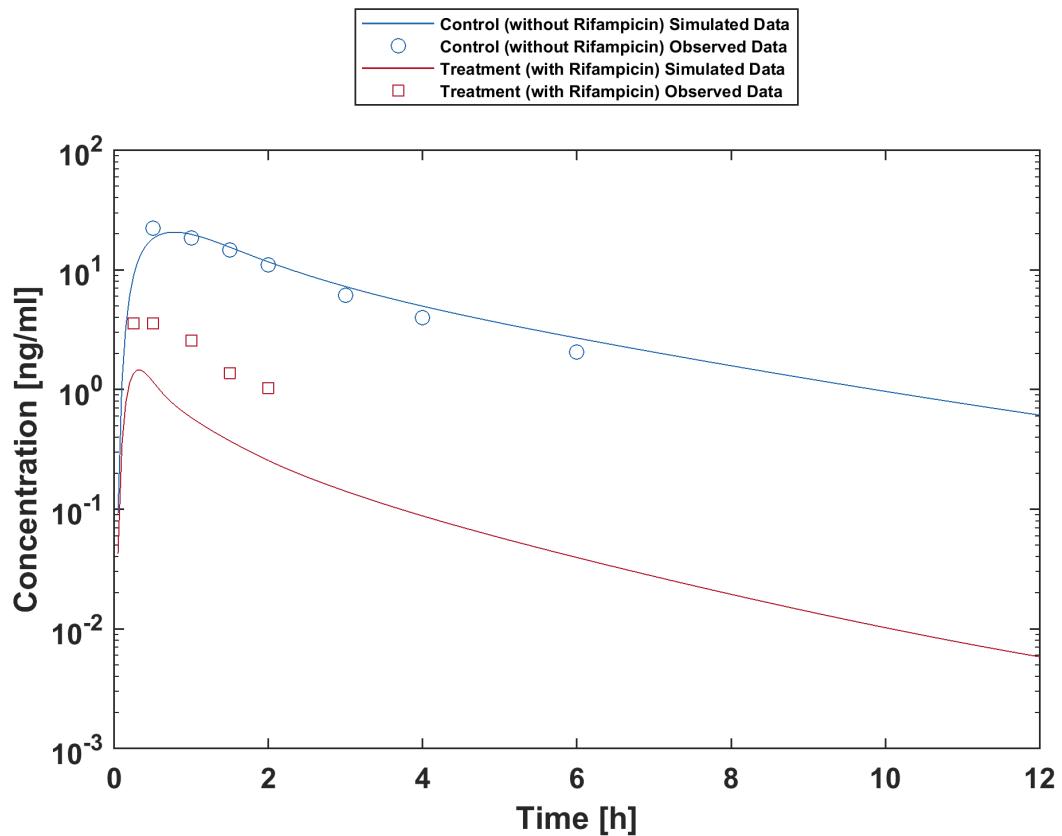
Backman 1998 (Phase IV and V vs. I)



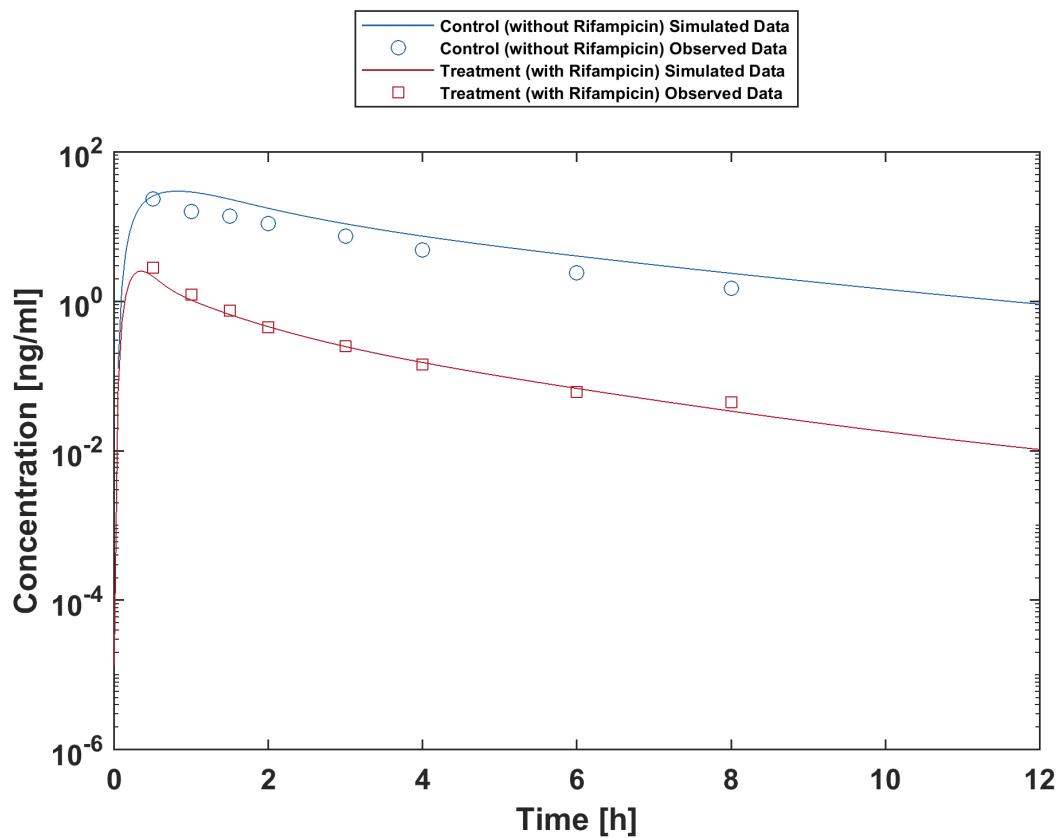
Björkhem-Bergman 2013



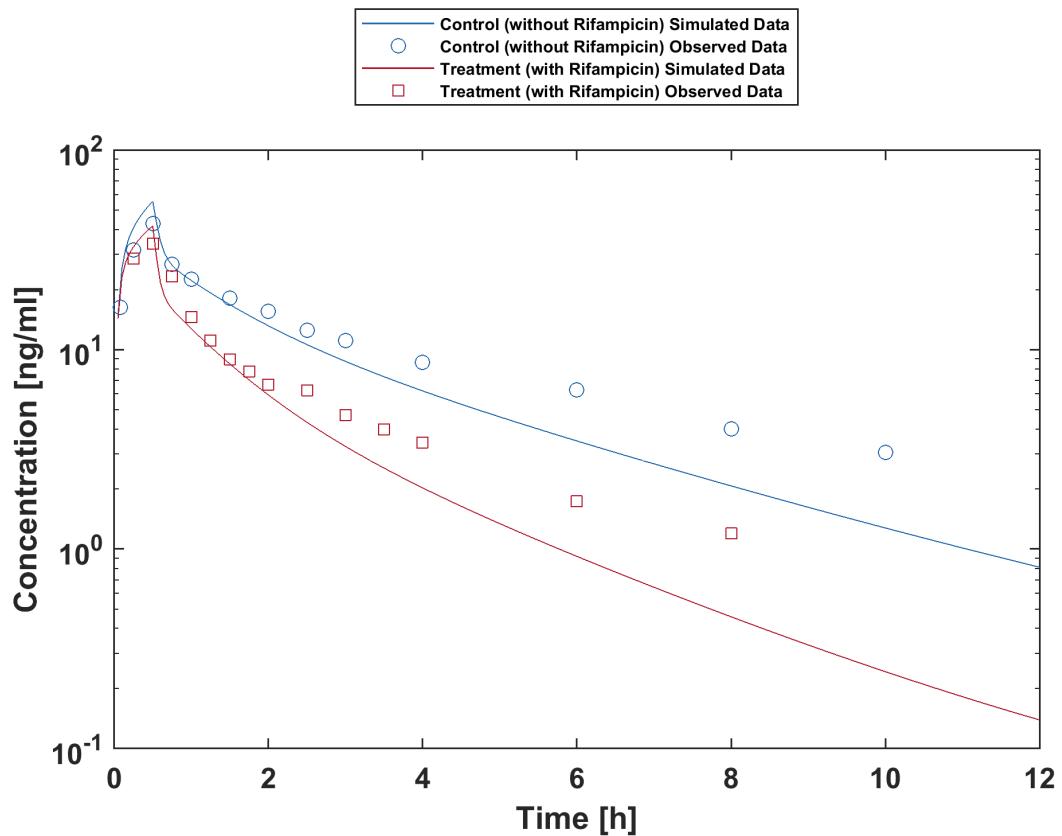
Chattopadhyay 2018



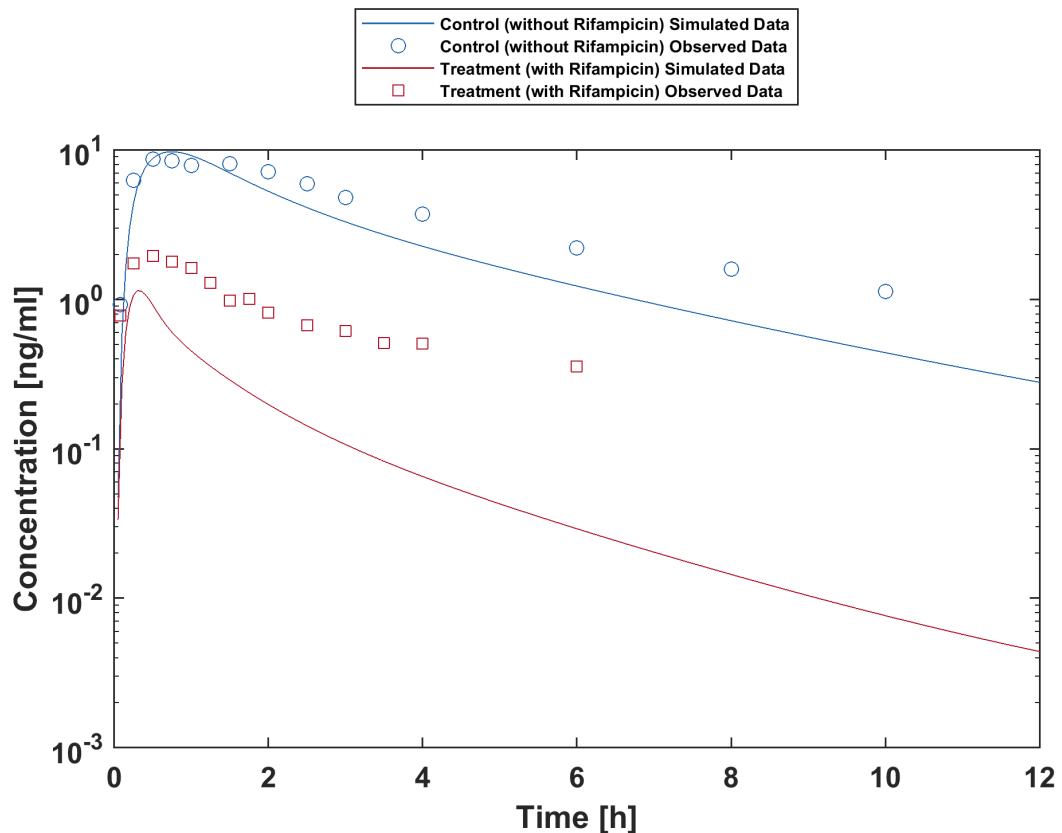
Chung 2006



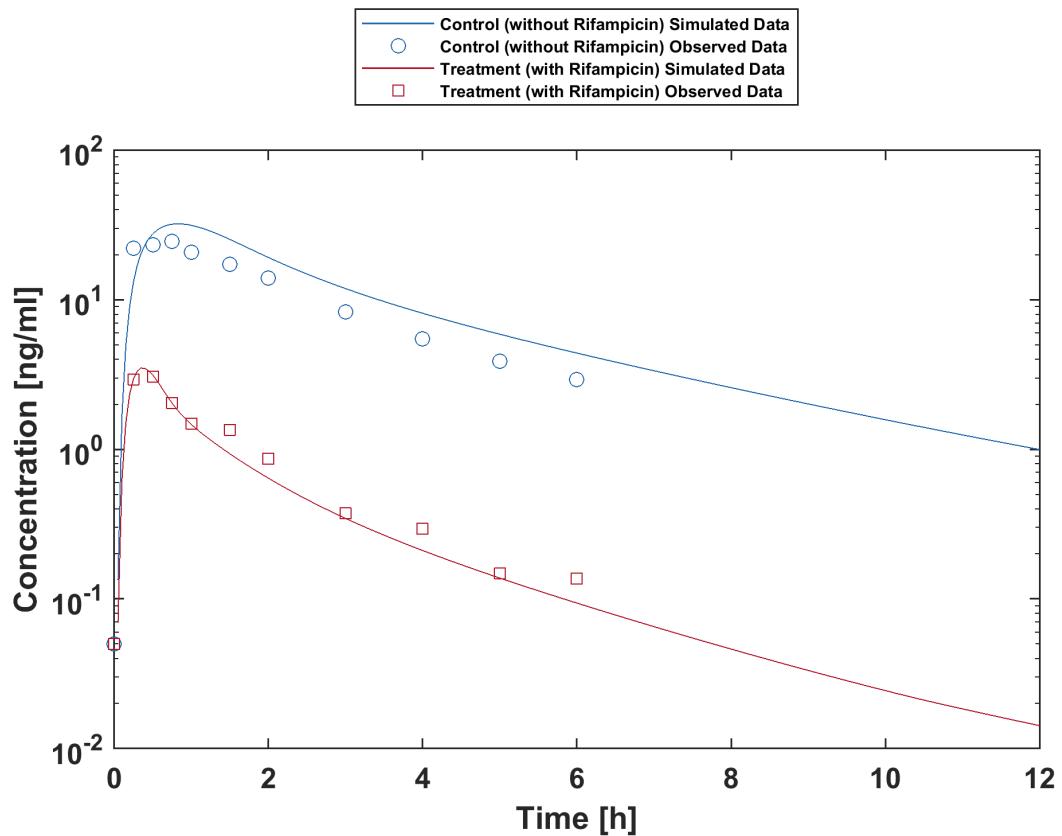
Eap 2004 (7.5 mg)



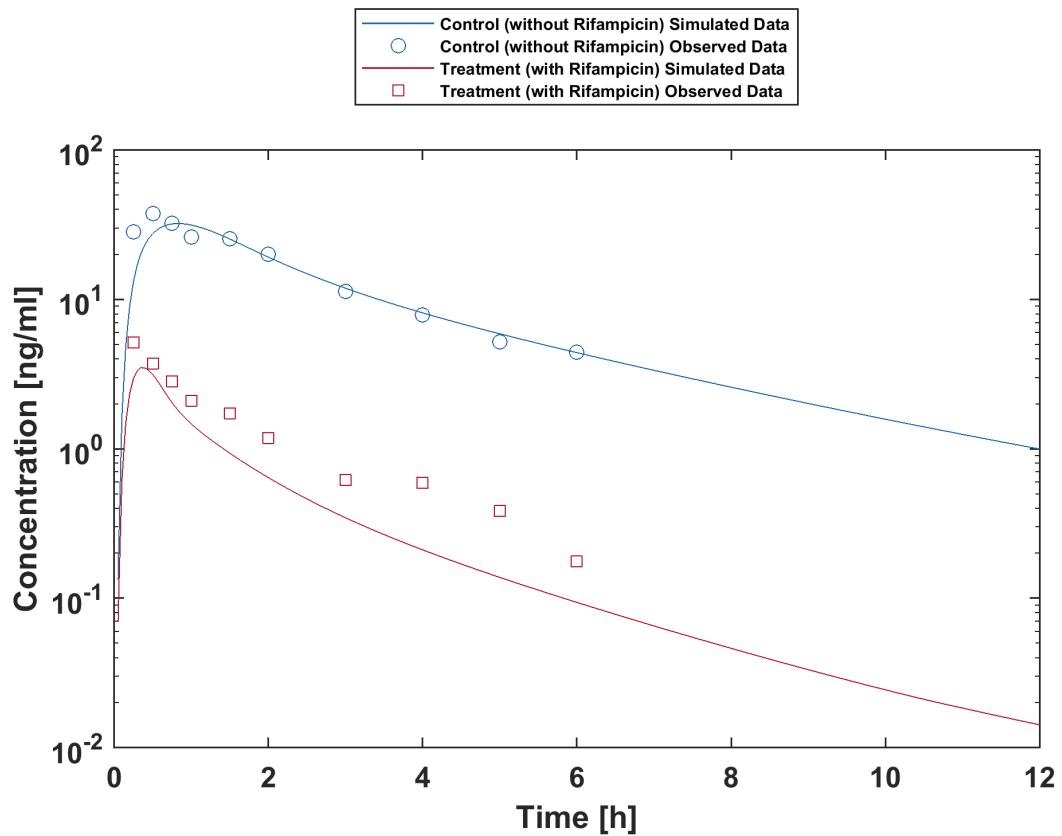
Gorski 2003 (iv)



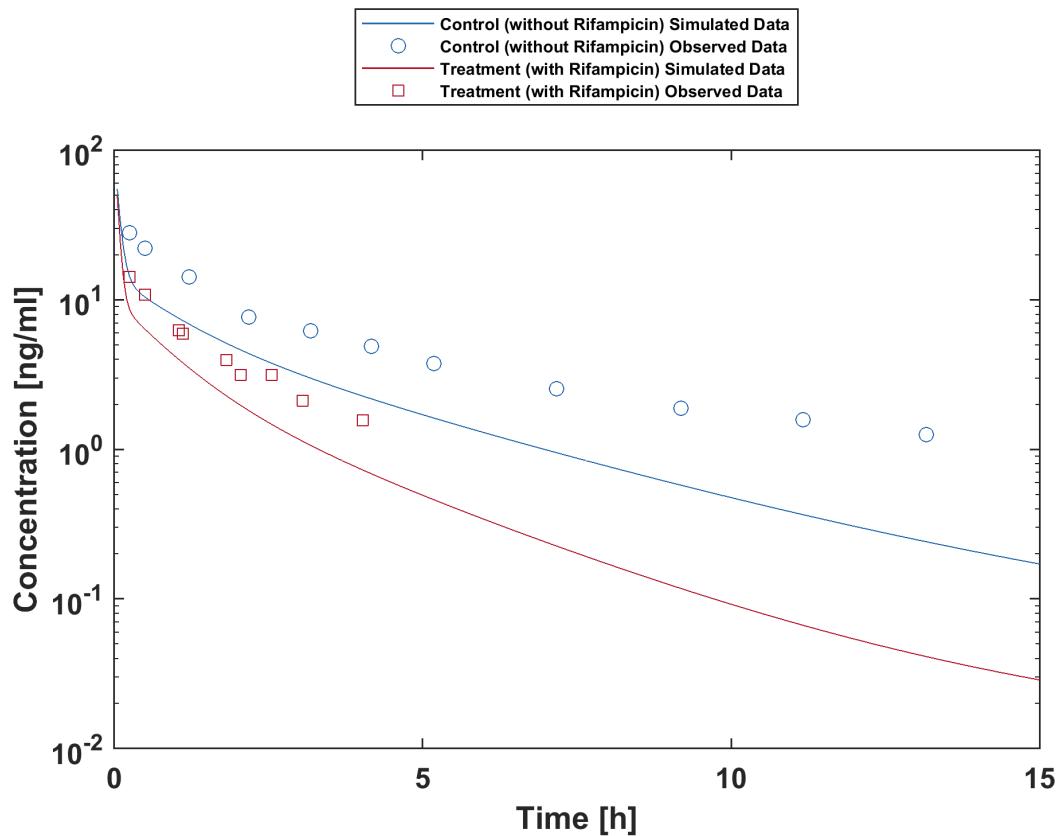
Gorski 2003 (po)



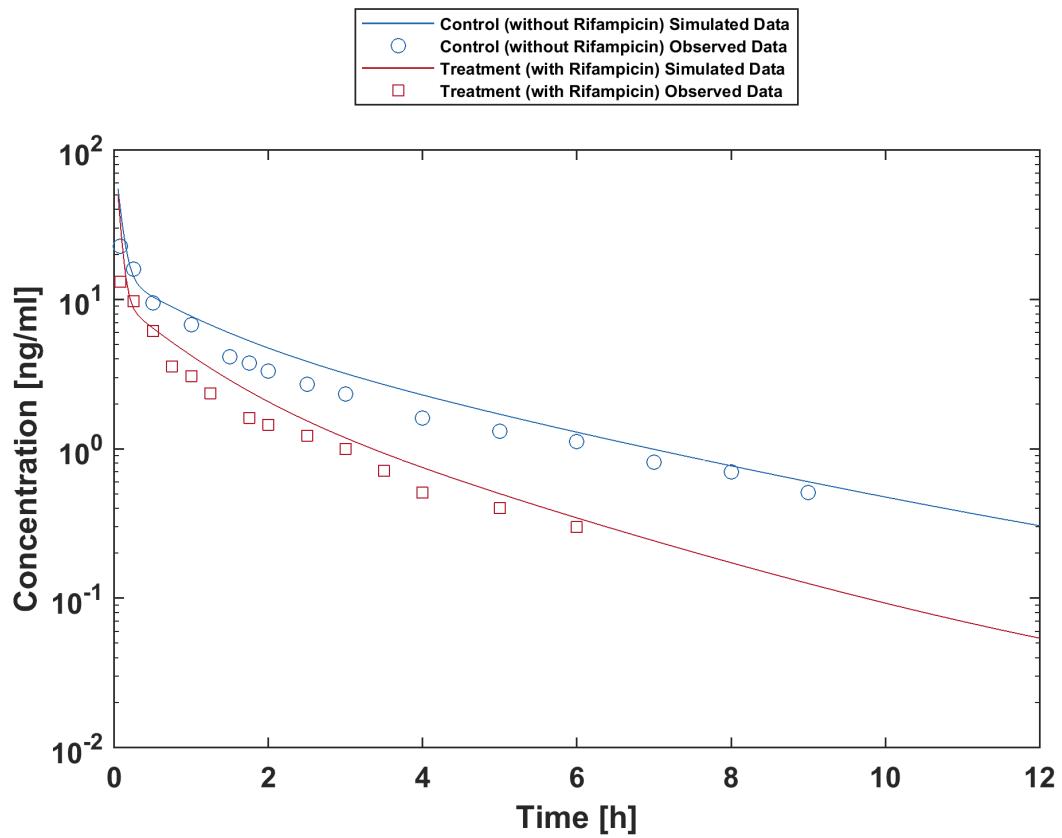
Gurley 2006



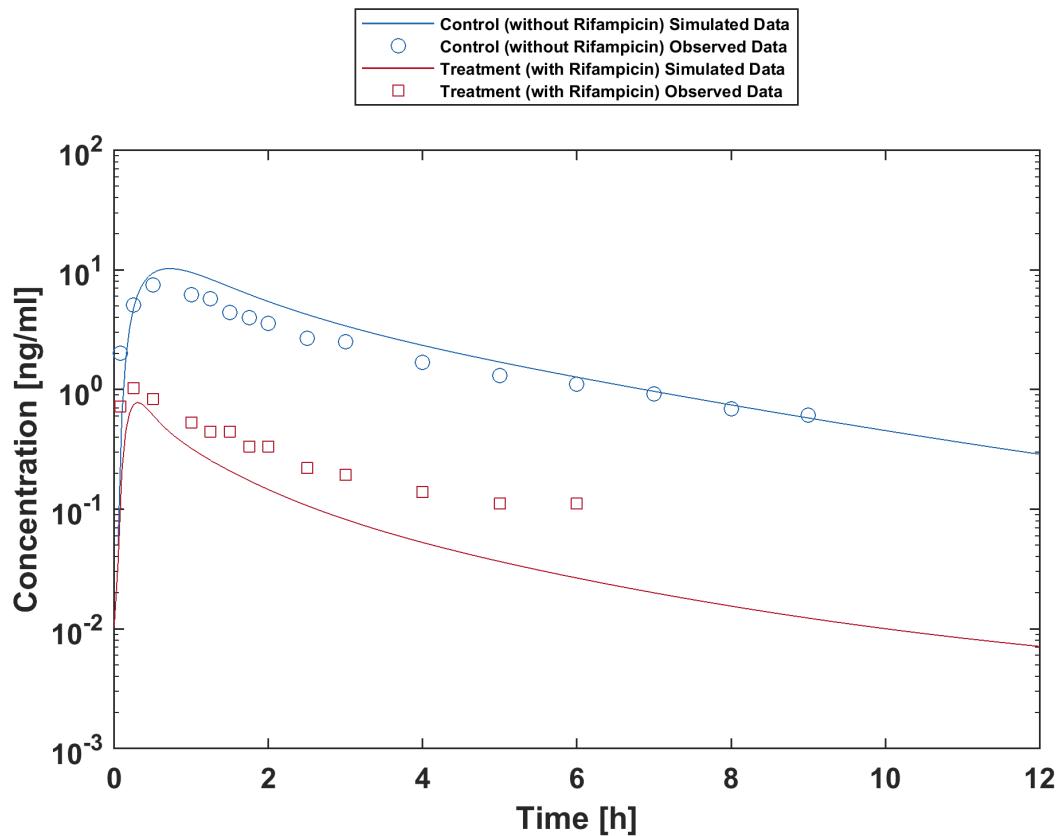
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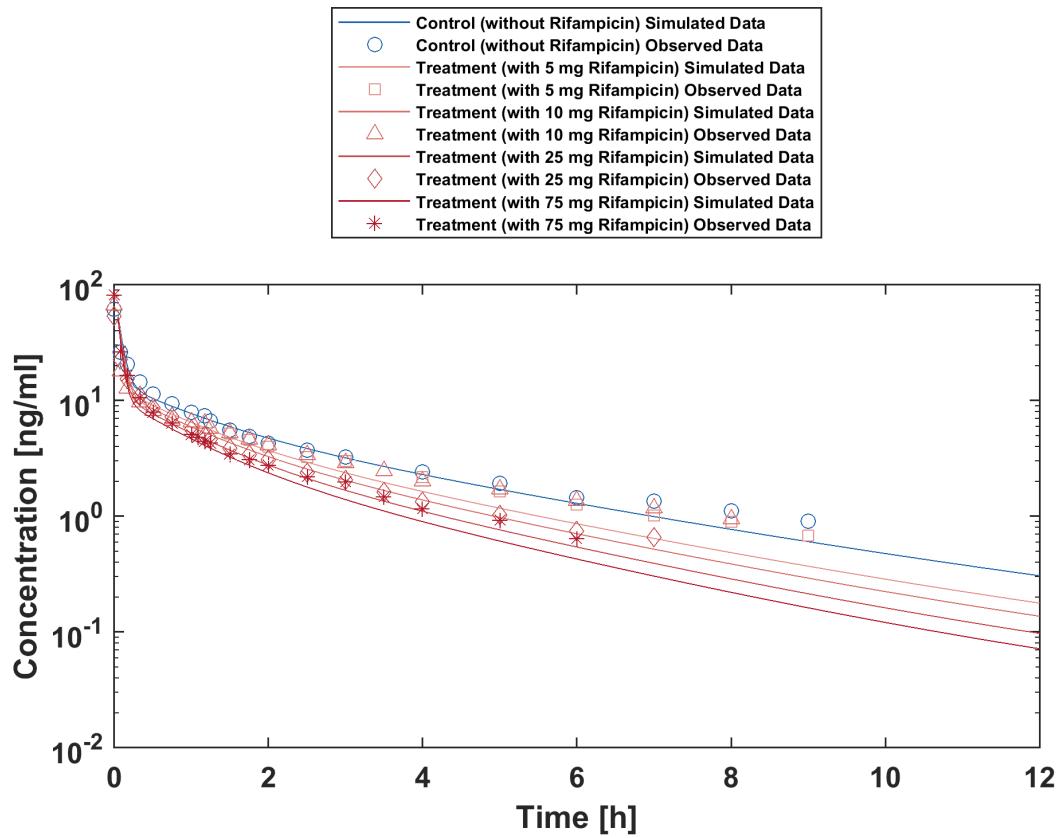
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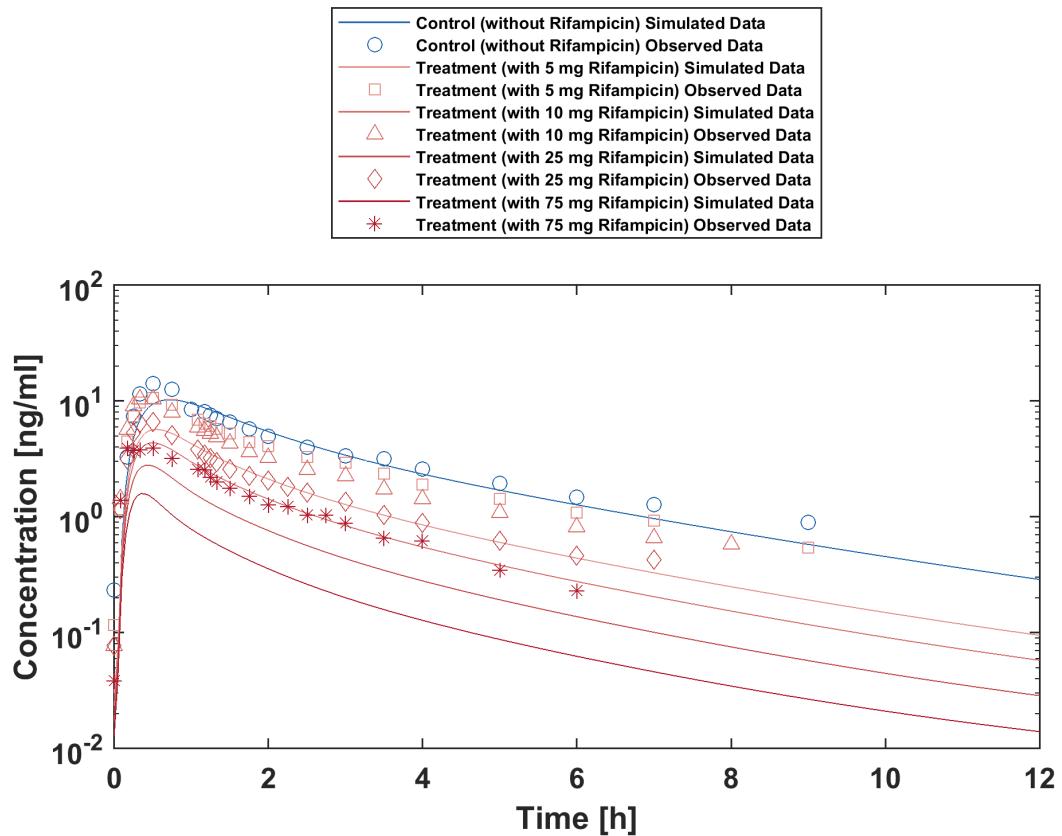
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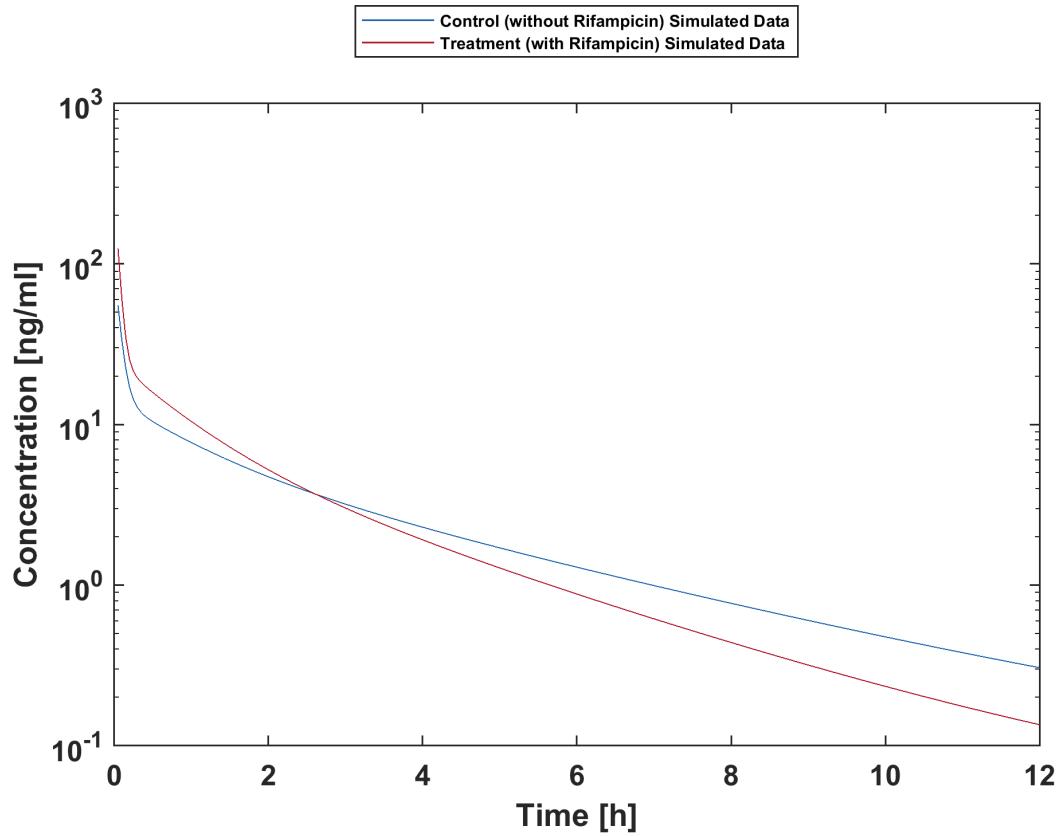
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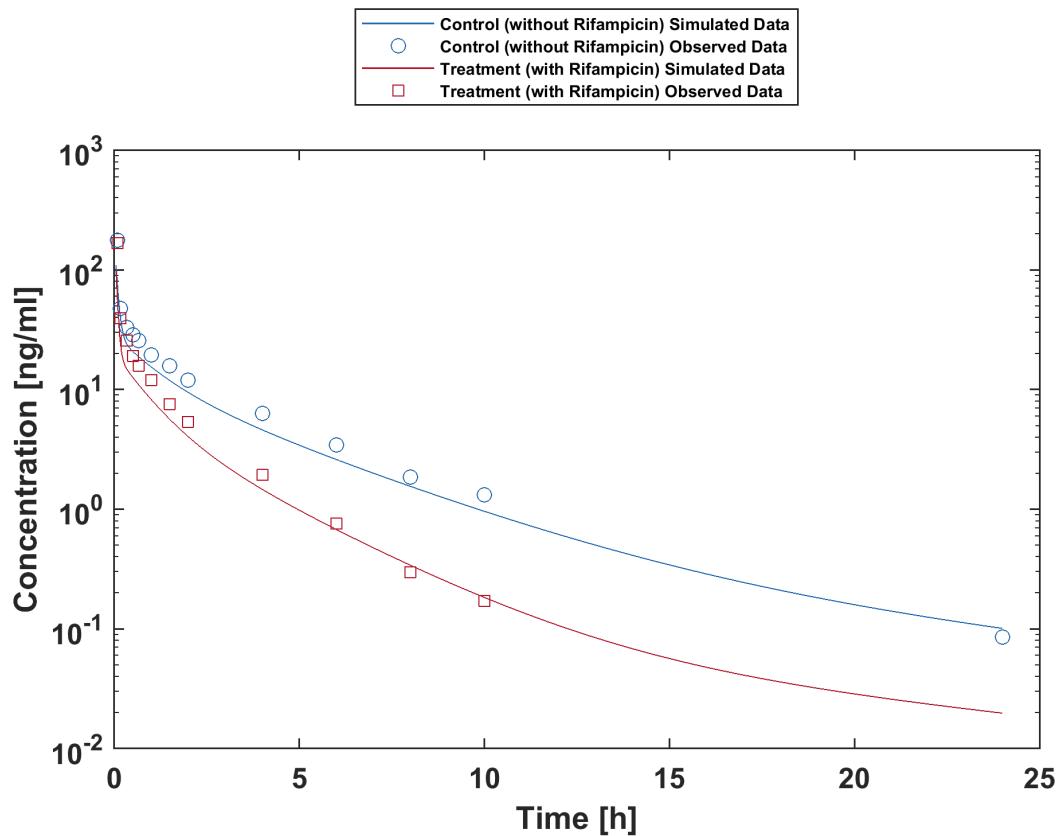
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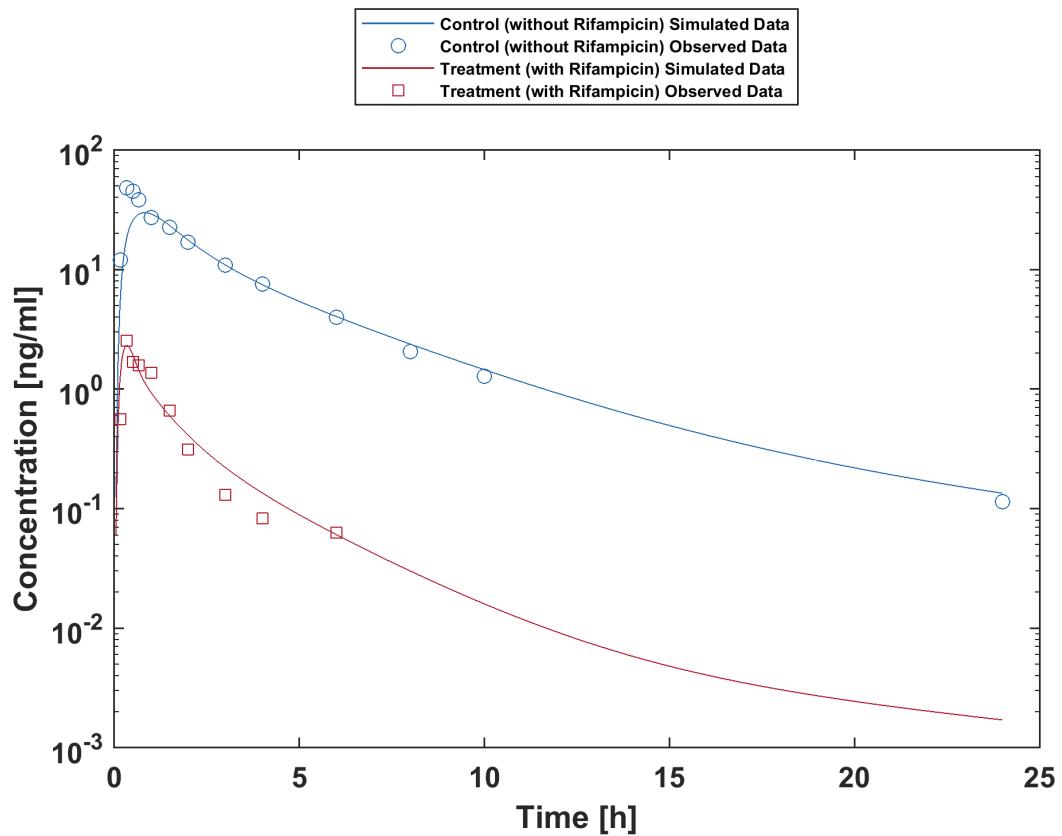
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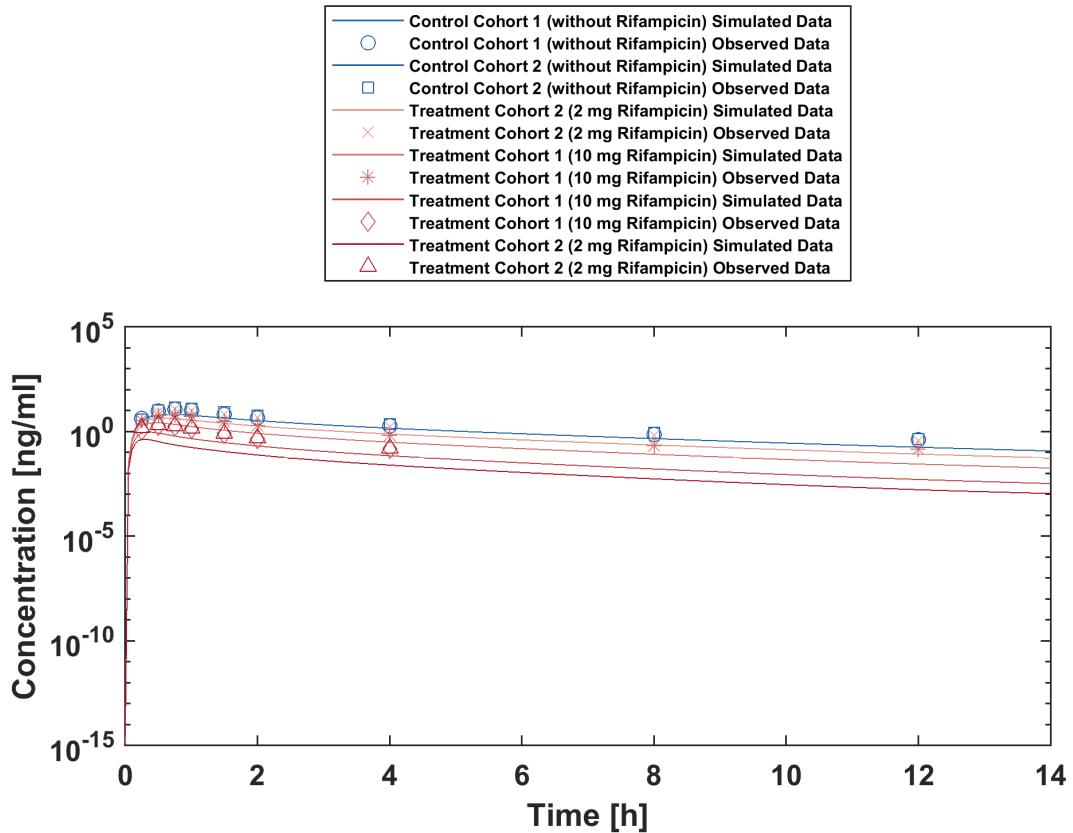
Kim 2018



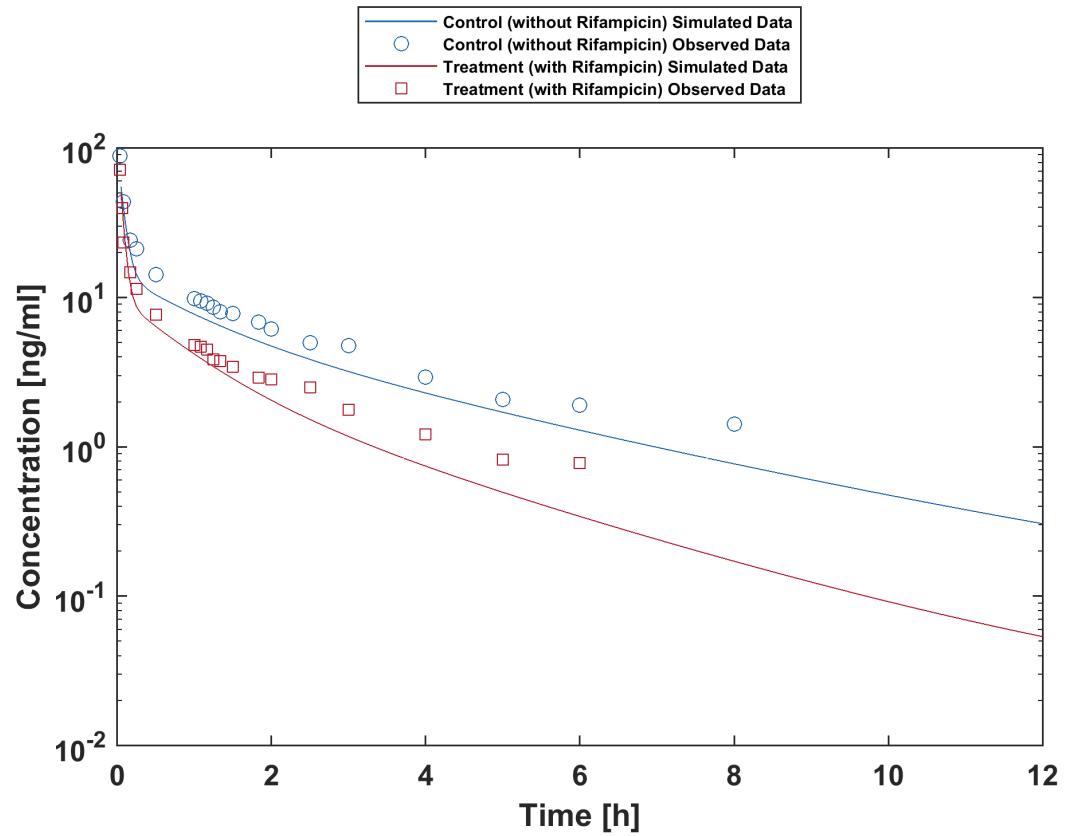
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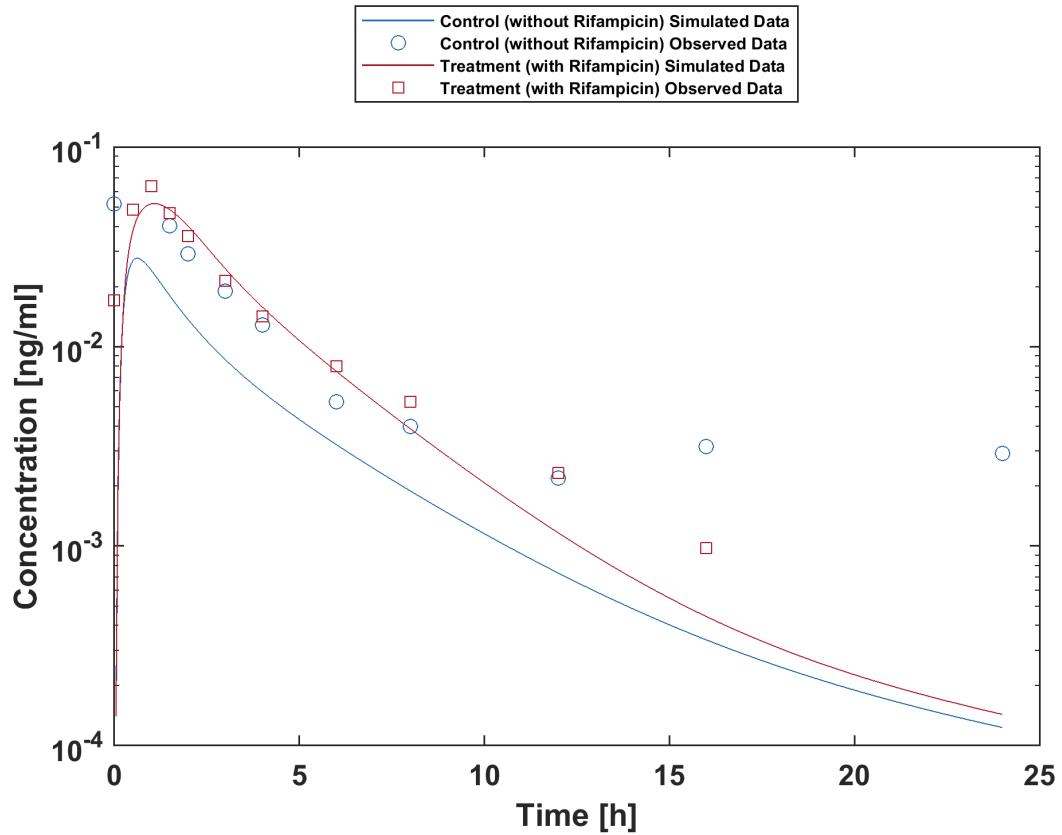
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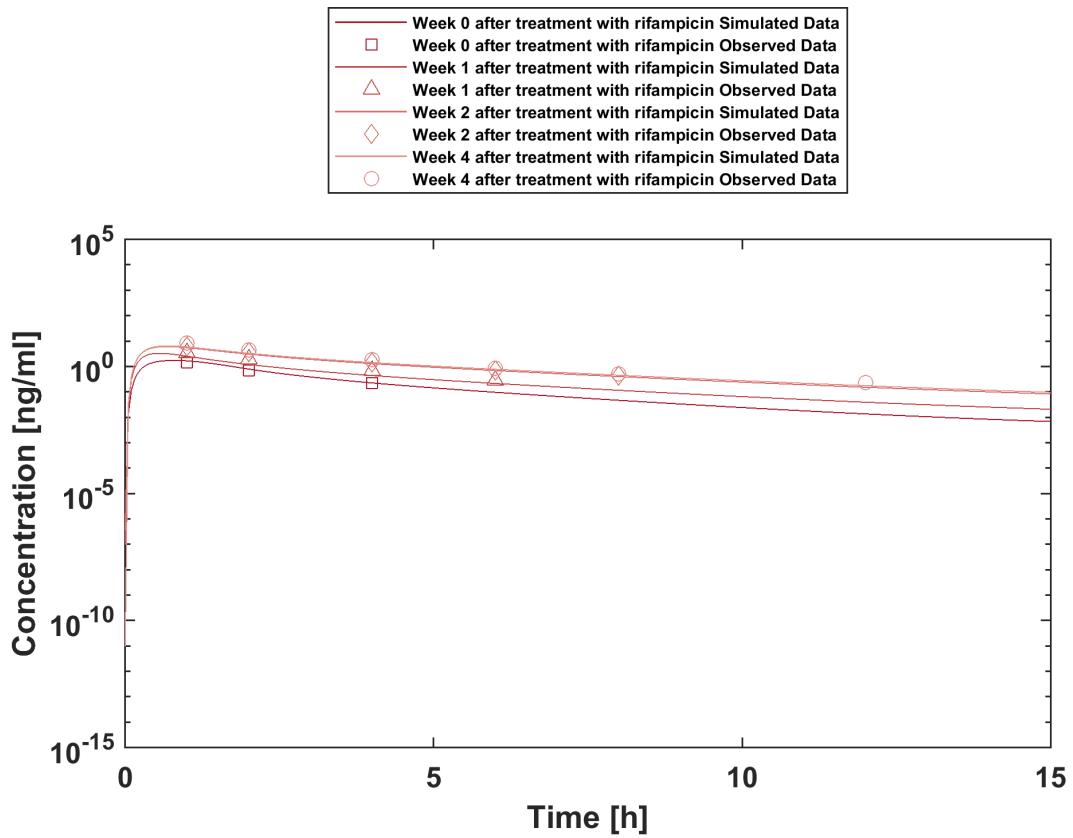
Lutz 2008



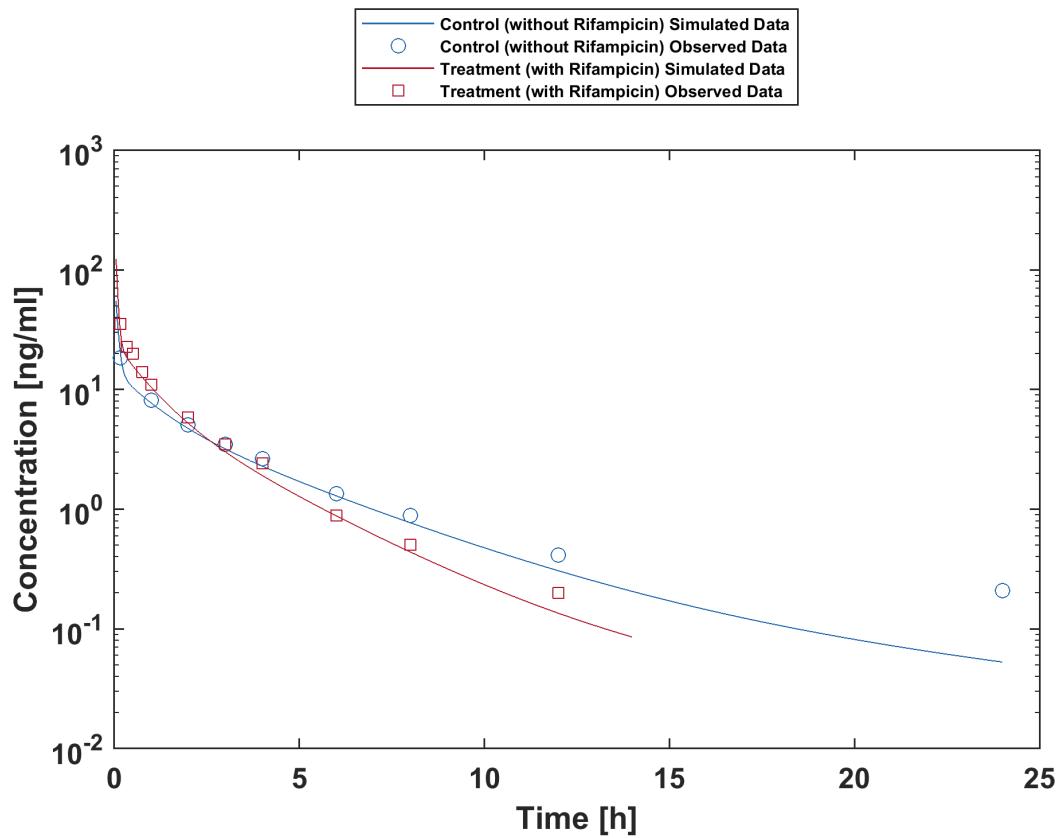
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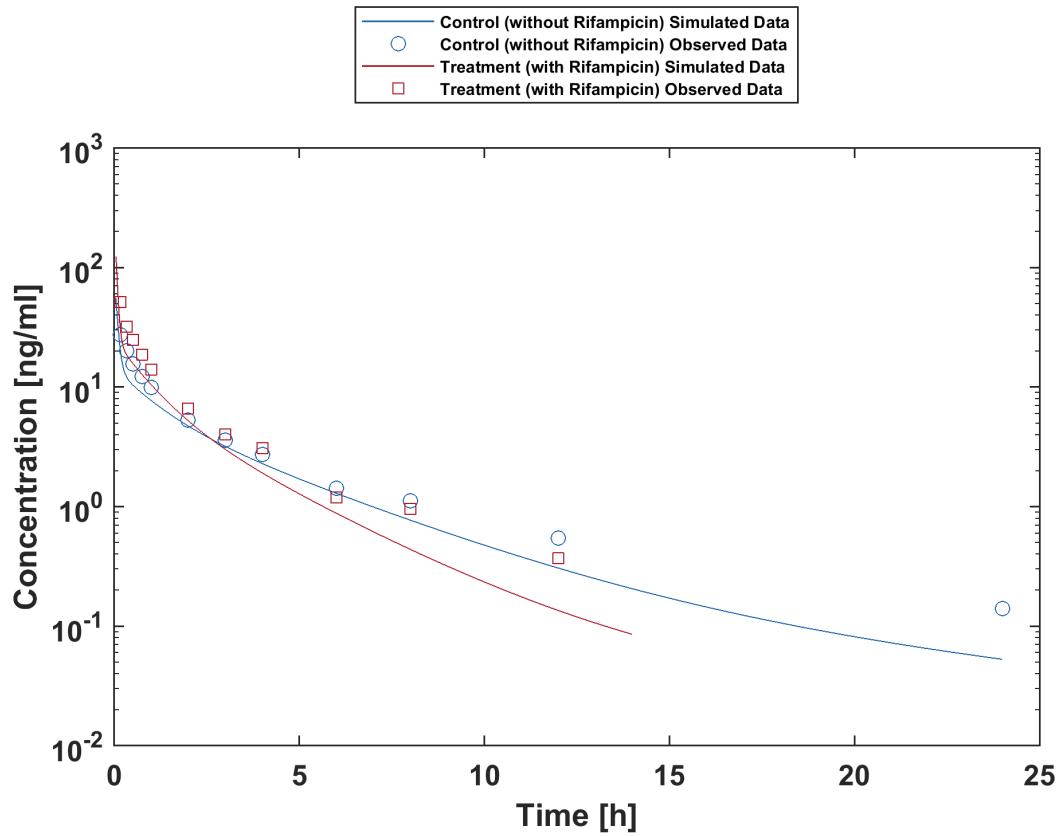
Pruksaritanont 2017



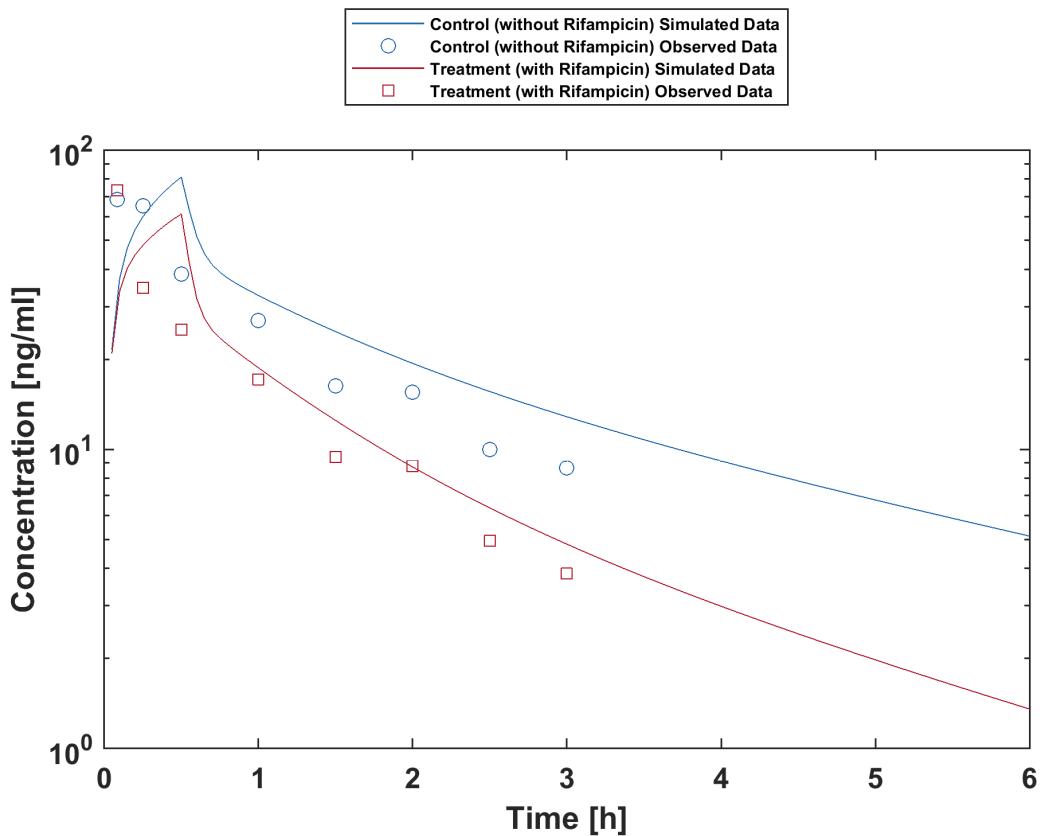
Reitman 2011



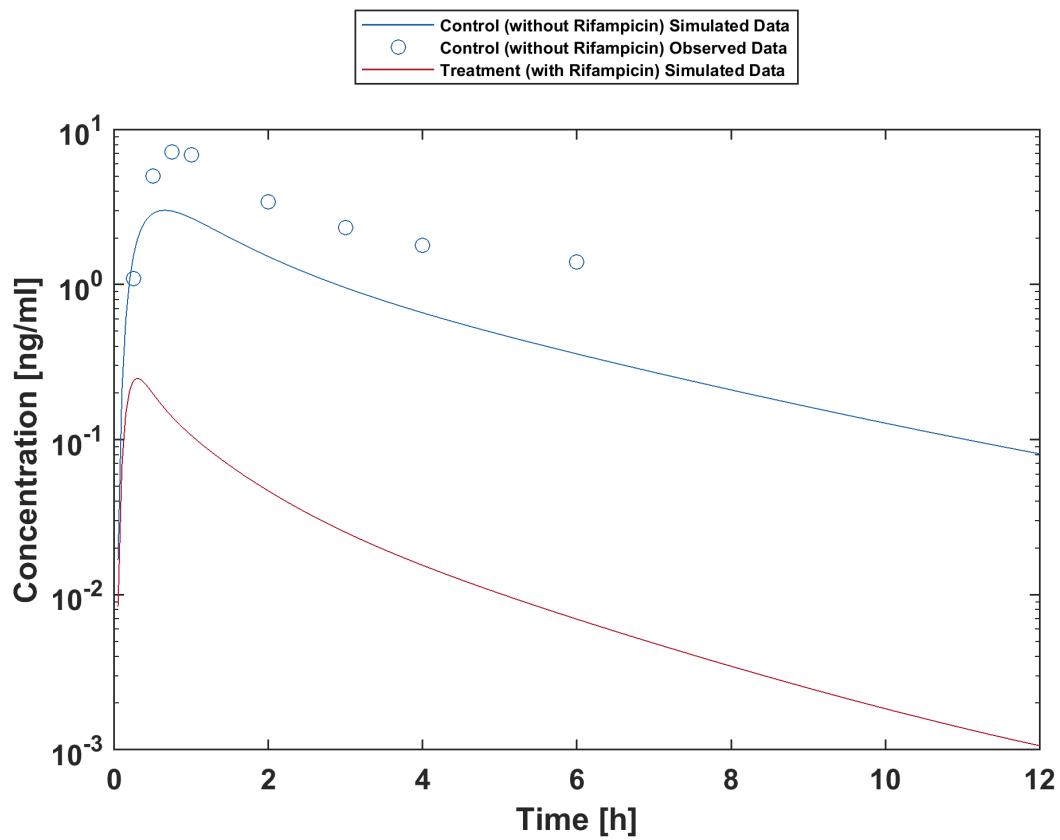
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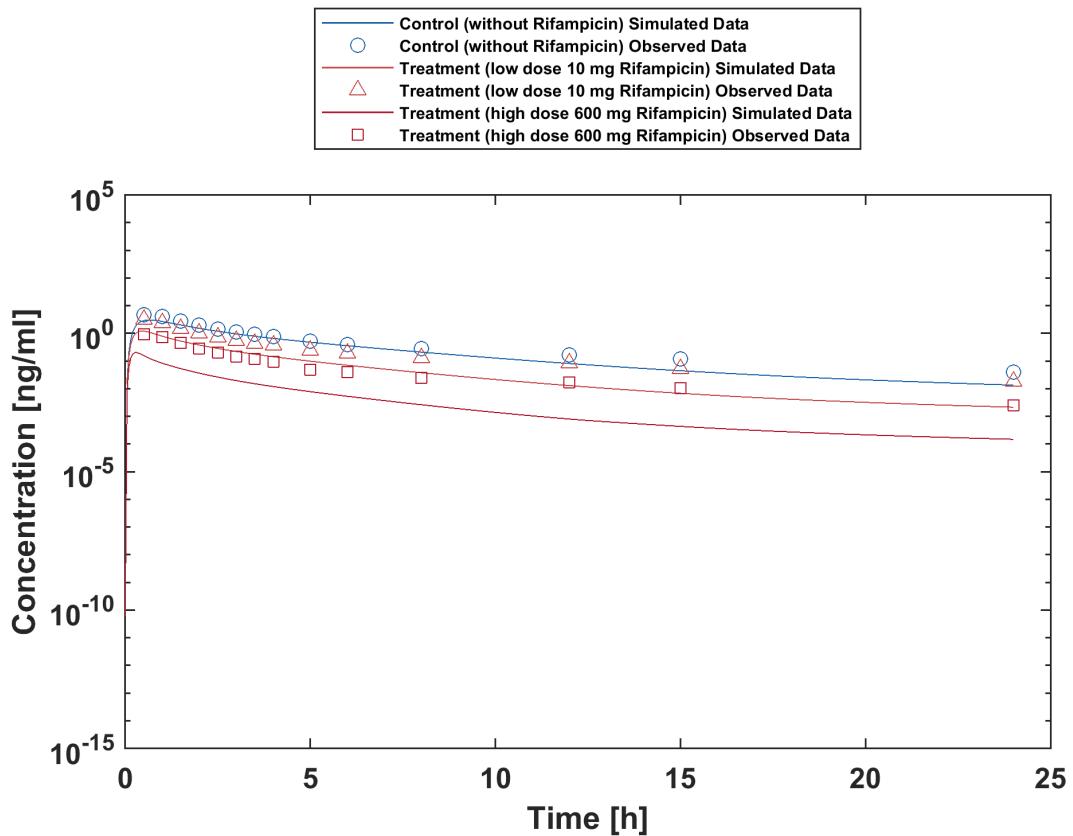
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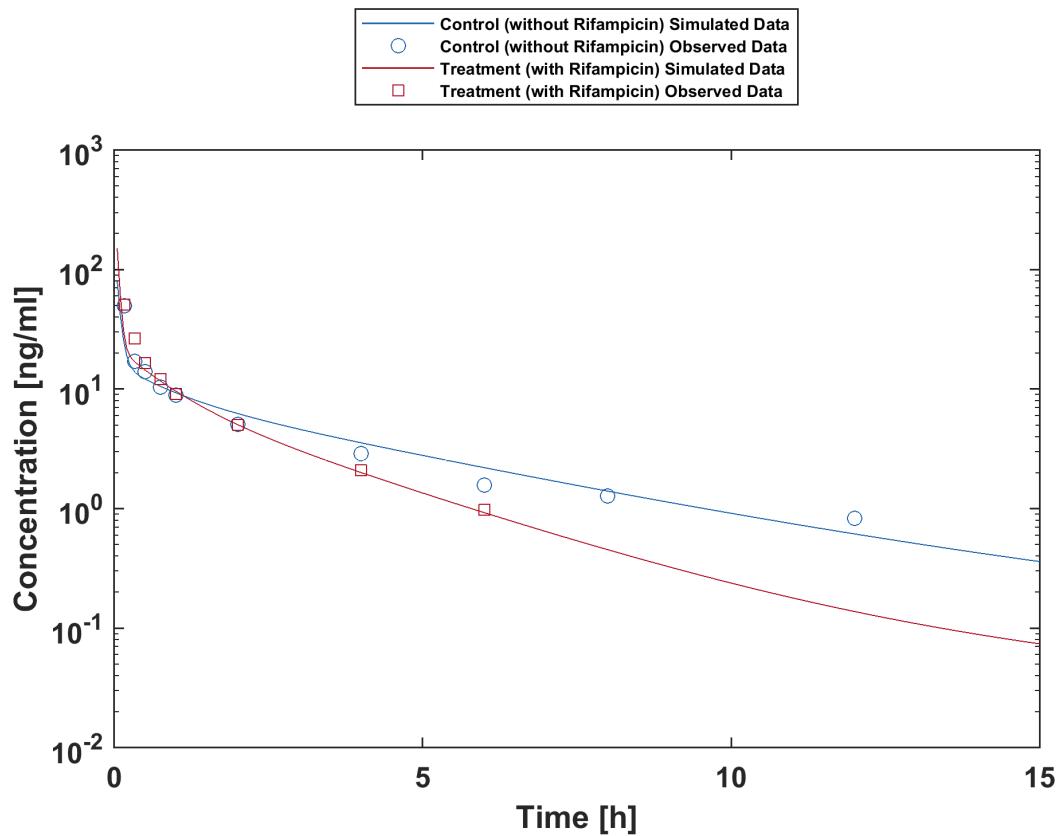
Szalat 2007



van Dyk 2018

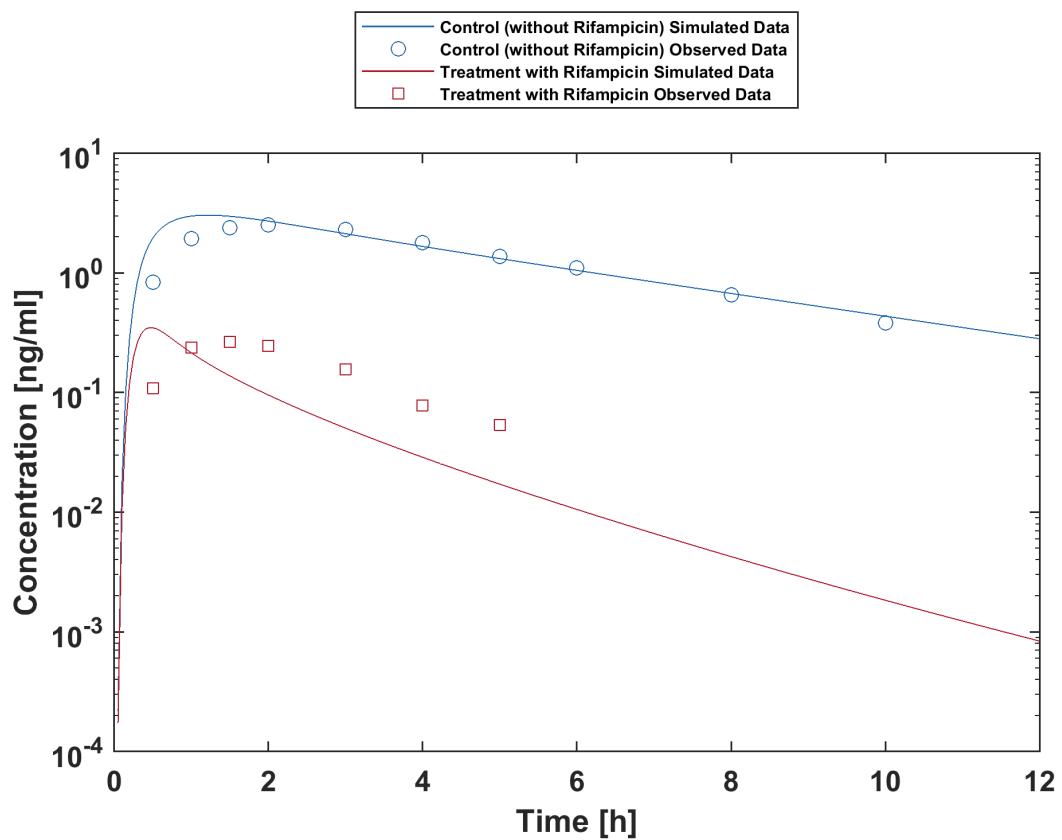


Wiesinger 2020



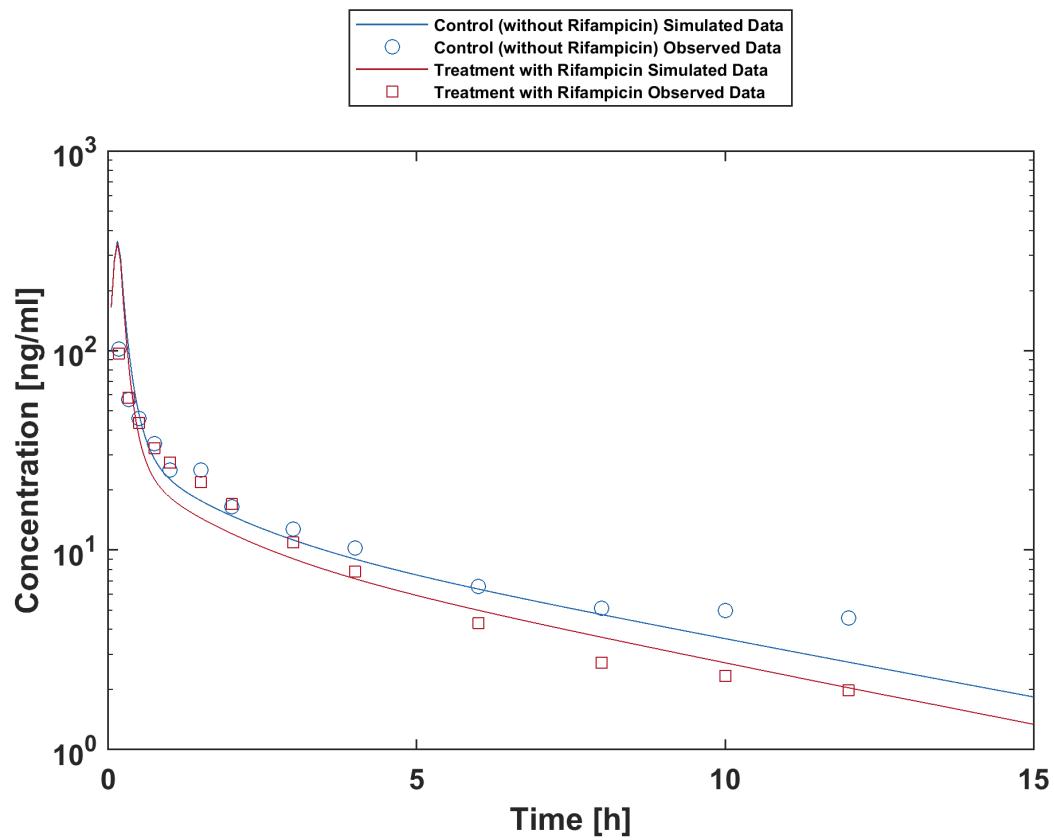
Yu 2004 (CYP3A5*3/*3)

3.31 Rifampicin - Triazolam DDI

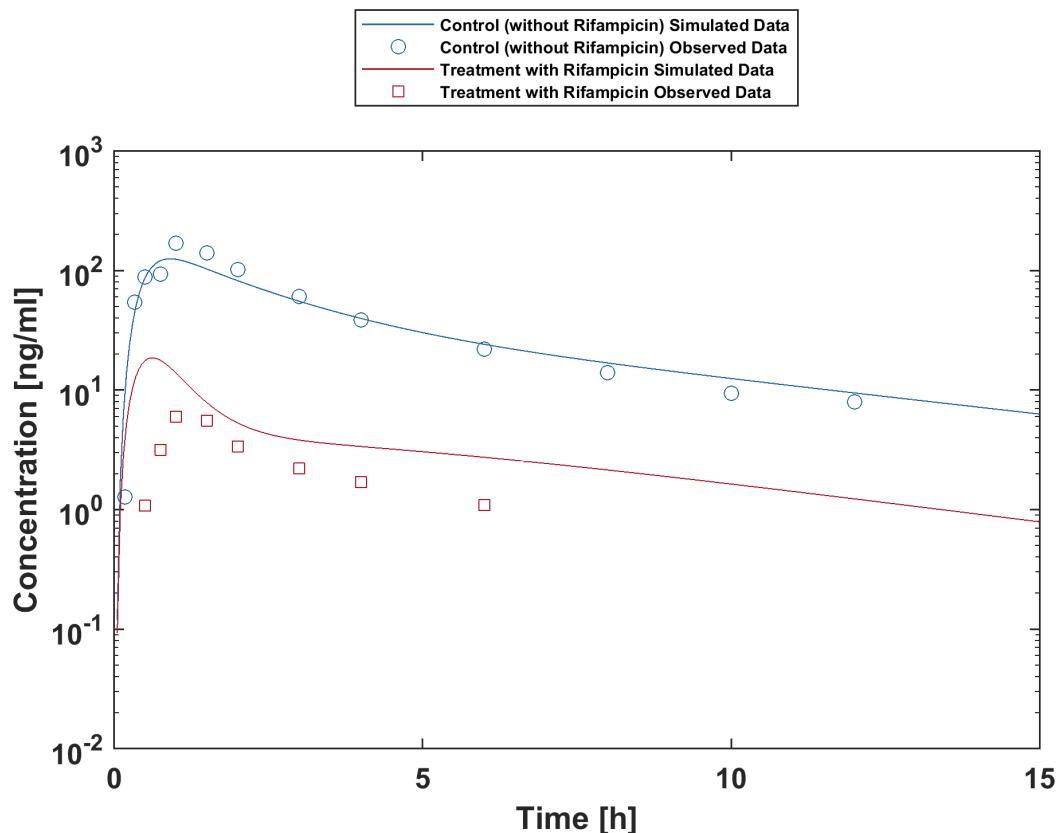


Villikka 1997

3.32 Rifampicin - Verapamil DDI

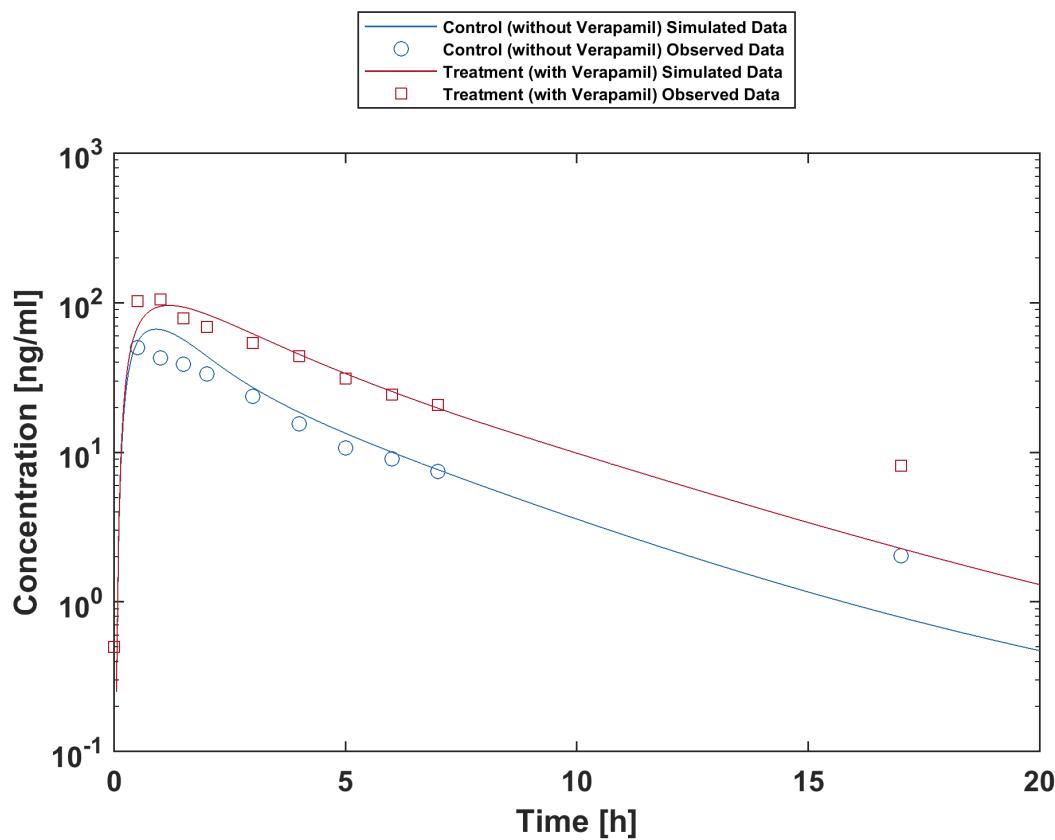


Barbarash 1988 (verapamil IV)

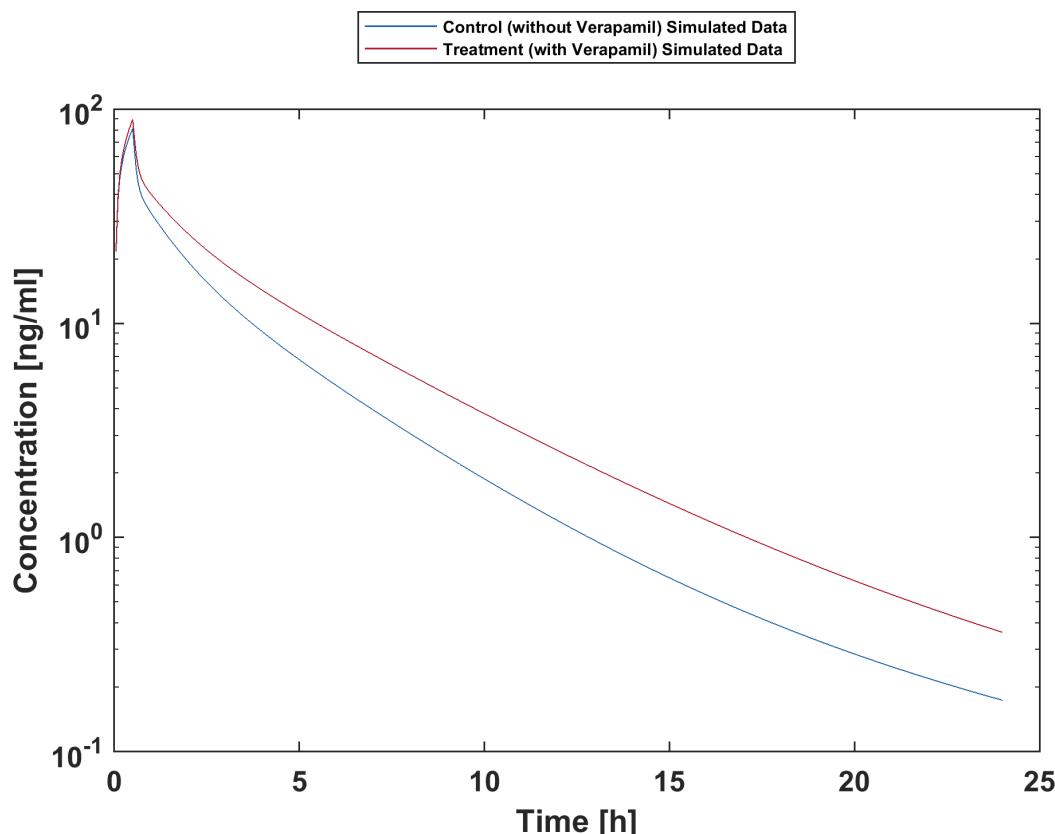


Barbarash 1988 (verapamil PO)

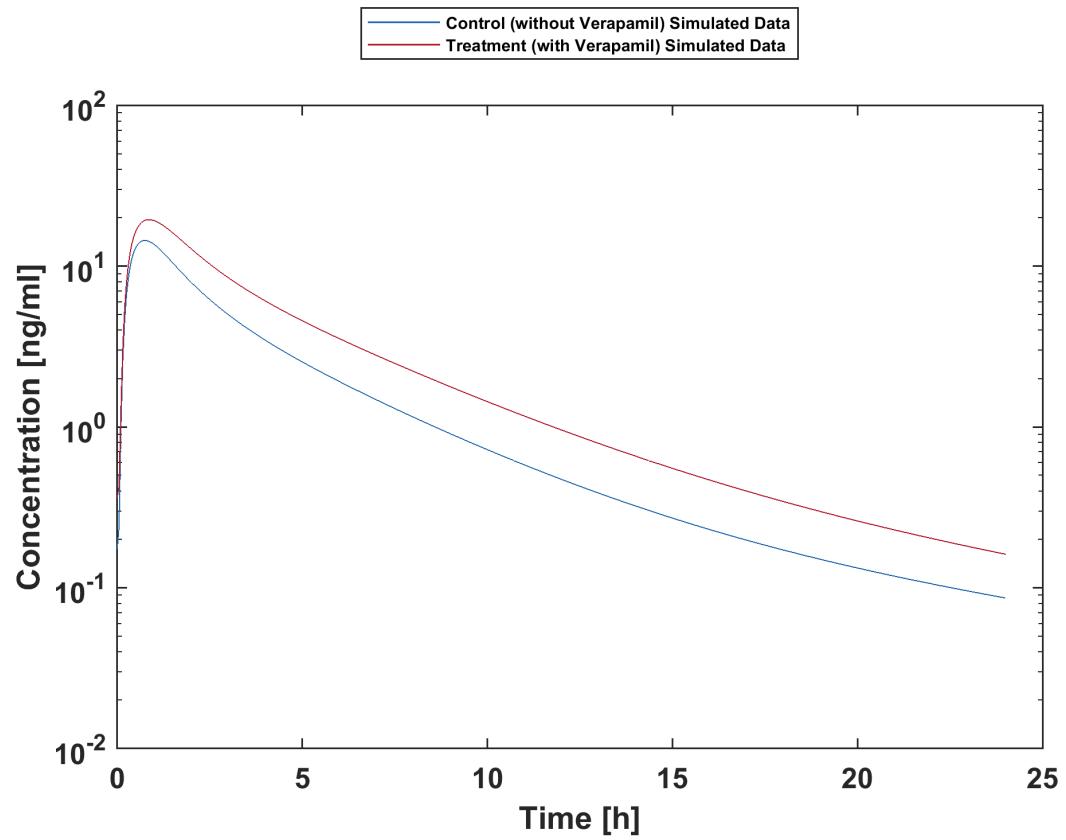
3.33 Verapamil - Midazolam DDI



Backman 1994



Wang 2005 (iv)



Wang 2005 (po)

4 References

Almond 2016 Almond LM, Mukadam S, Gardner I, Okialda K, Wong S, Hatley O, Tay S, Rowland-Yeo K, Jamei M, Rostami-Hodjegan A, Kenny JR. Prediction of Drug-Drug Interactions Arising from CYP3A induction Using a Physiologically Based Dynamic Model. *Drug Metab Dispos.* 2016 Jun;44(6):821-32.

Guest 2011 Guest EJ, Aarons L, Houston JB, Rostami-Hodjegan A, Galetin A. Critique of the two-fold measure of prediction success for ratios: application for the assessment of drug-drug interactions. *Drug Metab Dispos.* 2011 Feb;39(2):170-3.

OSP PK Database (<https://github.com/Open-Systems-Pharmacology/Database-for-observed-data>)

Carbamazepine-Alprazolam-DDI

Furukori 1998 Furukori, H., Otani, K., Yasui, N., et al. (2018). Effect of carbamazepine on the single oral dose pharmacokinetics of alprazolam. *Neuropsychopharmacology*, 18(5), 364-369.

Carbamazepine-Efavirenz-DDI

Ji 2008 Ji, P., Damle, B., Xie, J., Unger, S. E., Grasela, D. M., & Kaul, S. (2008). Pharmacokinetic interaction between efavirenz and carbamazepine after multiple-dose administration in healthy subjects. *The Journal of Clinical Pharmacology*, 48(8), 948-956.

Carbamazepine-Midazolam-DDI

Lutz 2018 Lutz, J. D., Kirby, B. J., Wang, L., et al. (2018). Cytochrome P450 3A induction predicts P-glycoprotein induction; part 2: prediction of decreased substrate exposure after rifabutin or carbamazepine. *Clinical Pharmacology & Therapeutics*, 104(6), 1191-1198.

Kanefendt 2023 Kanefendt, F., Dallmann, A., Chen, H., Francke, K., Liu, T., Bräse, C., Frechen, S., & Schultze-Mosgau, M. H. (2024). Assessment of the CYP3A4 Induction Potential by Carbamazepine: Insights from two Clinical DDI Studies and PBPK Modeling. *Clinical pharmacology and therapeutics*. doi: 10.1002/cpt.3151. Epub ahead of print.

Cimetidine-Alfentanil-DDI

Kienlen 1993 Kienlen, J., Levron, JC., Aubas, S. et al. Pharmacokinetics of Alfentanil in Patients Treated with Either Cimetidine or Ranitidine. *Drug Invest* 6, 257–262 (1993).

Cimetidine-Alprazolam-DDI

Pourbaix 1985 Pourbaix S, Desager JP, Hulhoven R, Smith RB, Harvengt C. Pharmacokinetic consequences of long term coadministration of cimetidine and triazolobenzodiazepines, alprazolam and triazolam, in healthy subjects. *Int J Clin Pharmacol Ther Toxicol.* 1985 Aug;23(8):447-51.

Abernethy 1983 Abernethy DR, Greenblatt DJ, Divoll M, Moschitto LJ, Harmatz JS, Shader RI. Interaction of cimetidine with the triazolobenzodiazepines alprazolam and triazolam. *Psychopharmacology (Berl)*. 1983;80(3):275-8. doi: 10.1007/BF00436169.

Cimetidine-Carbamazepine-DDI

Dalton 1985 Dalton, M. J., Powell, J. R., & Messenheimer Jr, J. A. (1985). The Influence of Cimetidine on Single-Dose Carbamazepine Pharmacokinetics. *Epilepsia*, 26(2), 127-130.

Cimetidine-Midazolam-DDI

Elliott 1984 Elliott P, Dundee JW, Elwood RJ, Collier PS. The influence of H₂ receptor antagonists on the plasma concentrations of midazolam and temazepam. *Eur J Anaesthesiol*. 1984 Sep;1(3):245-51.

Fee 1987 Fee JP, Collier PS, Howard PJ, Dundee JW. Cimetidine and ranitidine increase midazolam bioavailability. *Clin Pharmacol Ther*. 1987 Jan;41(1):80-4.

Greenblatt 1986 Greenblatt DJ, Locniskar A, Scavone JM, Blyden GT, Ochs HR, Harmatz JS, Shader RI. Absence of interaction of cimetidine and ranitidine with intravenous and oral midazolam. *Anesth Analg*. 1986 Feb;65(2):176-80.

Martinez 1999 Martínez C, Albet C, Agúndez JA, Herrero E, Carrillo JA, Márquez M, Benítez J, Ortiz JA. Comparative in vitro and in vivo inhibition of cytochrome P450 CYP1A2, CYP2D6, and CYP3A by H₂-receptor antagonists. *Clin Pharmacol Ther*. 1999 Apr;65(4):369-76.

Salonen 1986 Salonen M, Aantaa E, Aaltonen L, Kanto J. Importance of the interaction of midazolam and cimetidine. *Acta Pharmacol Toxicol (Copenh)*. 1986 Feb;58(2):91-5.

Cimetidine-Triazolam-DDI

Pourbaix 1985 Pourbaix S, Desager JP, Hulhoven R, Smith RB, Harvengt C. Pharmacokinetic consequences of long term coadministration of cimetidine and triazolobenzodiazepines, alprazolam and triazolam, in healthy subjects. *Int J Clin Pharmacol Ther Toxicol*. 1985 Aug;23(8):447-51.

Abernethy 1983 Abernethy DR, Greenblatt DJ, Divoll M, Moschitto LJ, Harmatz JS, Shader RI. Interaction of cimetidine with the triazolobenzodiazepines alprazolam and triazolam. *Psychopharmacology (Berl)*. 1983;80(3):275-8.

Cox 1986 Cox SR, Kroboth PD, Anderson PH, Smith RB. Mechanism for the interaction between triazolam and cimetidine. *Biopharm Drug Dispos*. 1986 Nov-Dec;7(6):567-75.

Friedman 1988 Friedman H, Greenblatt DJ, Burstein ES, Scavone JM, Harmatz JS, Shader RI. Triazolam kinetics: interaction with cimetidine, propranolol, and the combination. *J Clin Pharmacol*. 1988 Mar;28(3):228-33.

Cimetidine-Verapamil-DDI

Smith 1984 Smith MS, Benyunes MC, Bjornsson TD, Shand DG, Pritchett EL. Influence of cimetidine on verapamil kinetics and dynamics. *Clin Pharmacol Ther*. 1984 Oct;36(4):551-4.

Clarithromycin-Midazolam-DDI

Gorski 1998 Gorski, J. C., Jones, D. R., Haehner-Daniels, B. D., Hamman, M. A., O'Mara Jr, E. M., & Hall, S. D. (1998). The contribution of intestinal and hepatic CYP3A to the interaction between midazolam and clarithromycin. *Clinical Pharmacology & Therapeutics*, 64(2), 133-143.

Gurley 2006 Gurley, B., Hubbard, M. A., Williams, D. K., Thaden, J., Tong, Y., Gentry, W. B., ... & Cheboyina, S. (2006). Assessing the clinical significance of botanical supplementation on human cytochrome P450 3A activity: comparison of a milk thistle and black cohosh product to rifampin and clarithromycin. *The Journal of Clinical Pharmacology*, 46(2), 201-213.

Gurley 2008a Gurley, B. J., Swain, A., Hubbard, M. A., Hartsfield, F., Thaden, J., Williams, D. K., ... & Tong, Y. (2008). Supplementation with goldenseal (*Hydrastis canadensis*), but not kava kava (*Piper methysticum*), inhibits human CYP3A activity in vivo. *Clinical Pharmacology & Therapeutics*, 83(1), 61-69.

Markert 2013 Markert, C., Hellwig, R., Burhenne, J., Hoffmann, M. M., Weiss, J., Mikus, G., & Haefeli, W. E. (2013). Interaction of ambrisentan with clarithromycin and its modulation by polymorphic SLCO1B1. *European journal of clinical pharmacology*, 69(10), 1785-1793.

Prueksaritanont 2017 Prueksaritanont, T., Tatosian, D. A., Chu, X., Railkar, R., Evers, R., Chavez-Eng, C., ... & Cai, X. (2017). Validation of a microdose probe drug cocktail for clinical drug interaction assessments for drug transporters and CYP3A. *Clinical Pharmacology & Therapeutics*, 101(4), 519-530.

Quinney 2008 Quinney, S. K., Haehner, B. D., Rhoades, M. B., Lin, Z., Gorski, J. C., & Hall, S. D. (2008). Interaction between midazolam and clarithromycin in the elderly. *British journal of clinical pharmacology*, 65(1), 98-109.

van Dyk 2018 van Dyk, M., Marshall, J. C., Sorich, M. J., Wood, L. S., & Rowland, A. (2018). Assessment of inter-racial variability in CYP3A4 activity and inducibility among healthy adult males of Caucasian and South Asian ancestries. *European journal of clinical pharmacology*, 74(7), 913-920.

Yeates 1996 Yeates, R. A., Laufen, H., & Zimmermann, T. (1996). Interaction between midazolam and clarithromycin: comparison with azithromycin. *International journal of clinical pharmacology and therapeutics*, 34(9), 400-405.

Clarithromycin-Triazolam-DDI

Greenblatt 1998a Greenblatt DJ, von Moltke LL, Harmatz JS, Counihan M, Graf JA, Durol AL, Mertzanis P, Duan SX, Wright CE, Shader RI. Inhibition of triazolam clearance by macrolide antimicrobial agents: in vitro correlates and dynamic consequences. *Clin Pharmacol Ther*. 1998 Sep;64(3):278-85.

Efavirenz-Alfentanil-DDI

Kharasch 2012 Kharasch ED, Whittington D, Ensign D, Hoffer C, Bedynek PS, Campbell S, Stubbert K, Crafford A, London A, Kim T. Mechanism of efavirenz influence on methadone pharmacokinetics and pharmacodynamics. *Clin Pharmacol Ther*. 2012 Apr;91(4):673-84.

Efavirenz-Carbamazepine-DDI

Ji 2008 Ji, P., Damle, B., Xie, J., Unger, S. E., Grasela, D. M., & Kaul, S. (2008). Pharmacokinetic interaction between efavirenz and carbamazepine after multiple-dose administration in healthy subjects. *The Journal of Clinical Pharmacology*, 48(8), 948-956.

Efavirenz-Midazolam-DDI

Katzenmaier 2010 Katzenmaier S, Markert C, Mikus G. Proposal of a new limited sampling strategy to predict CYP3A activity using a partial AUC of midazolam. *Eur J Clin Pharmacol.* 2010 Nov;66(11):1137-41.

Mikus 2017 Mikus G, Heinrich T, Bödigheimer J, Röder C, Matthee AK, Weiss J, Burhenne J, Haefeli WE. Semisimultaneous Midazolam Administration to Evaluate the Time Course of CYP3A Activation by a Single Oral Dose of Efavirenz. *J Clin Pharmacol.* 2017 Jul;57(7):899-905.

Erythromycin-Alfentanil-DDI

Bartkowski 1989 Bartkowski, R. R., Goldberg, M. E., Larijani, G. E., & Boerner, T. (1989). Inhibition of alfentanil metabolism by erythromycin. *Clinical Pharmacology & Therapeutics*, 46(1), 99-102.

Bartkowski 1993 Bartkowski, R. R., Goldberg, M. E., Huffnagle, S., & Epstein, R. H. (1993). Sufentanil disposition. Is it affected by erythromycin administration?. *Anesthesiology*, 78(2), 260-265.

Erythromycin-Alprazolam-DDI

Yasui 1996 Yasui, N., Otani, K., Kaneko, S., Ohkubo, T., Osanai, T., Sugawara, K., ... & Ishizaki, T. (1996). A kinetic and dynamic study of oral alprazolam with and without erythromycin in humans: in vivo evidence for the involvement of CYP3A4 in alprazolam metabolism. *Clinical Pharmacology & Therapeutics*, 59(5), 514-519.

Erythromycin-Carbamazepine-DDI

Barzaghi 1987 Barzaghi, N., Gatti, G., Crema, F., Monteleone, M., Amione, C., Leone, L., & Perucca, E. (1987). Inhibition by erythromycin of the conversion of carbamazepine to its active 10, 11-epoxide metabolite. *British journal of clinical pharmacology*, 24(6), 836-838.

Miles 1989 Miles, M. V., & Tennison, M. B. (1989). Erythromycin effects on multiple-dose carbamazepine kinetics. *Therapeutic drug monitoring*, 11(1), 47-52.

Wong 1983 Wong, Y. Y., Ludden, T. M., & Bell, R. D. (1983). Effect of erythromycin on carbamazepine kinetics. *Clinical Pharmacology & Therapeutics*, 33(4), 460-464.

Erythromycin-Midazolam-DDI

Carls 2014 Carls, A., Jedamzik, J., Witt, L., Hohmann, N., Burhenne, J., & Mikus, G. (2014). Systemic exposure of topical erythromycin in comparison to oral administration and the effect on cytochrome P450 3A4 activity. *British journal of clinical pharmacology*, 78(6), 1433-1440.

Okudaira 2007 Okudaira, T., Kotegawa, T., Imai, H., Tsutsumi, K., Nakano, S., & Ohashi, K. (2007). Effect of the treatment period with erythromycin on cytochrome P450 3A activity in humans. *The Journal of Clinical Pharmacology*, 47(7), 871-876.

Olkkola 1993 Olkkola, K. T., Aranko, K., Luurila, H., Hiller, A., Saarnivaara, L., Himberg, J. J., & Neuvonen, P. J. (1993). A potentially hazardous interaction between erythromycin and midazolam. *Clinical Pharmacology & Therapeutics*, 53(3), 298-305.

Swart 2002 Swart, E. L., van der Hoven, B., Johan Groeneveld, A. B., Touw, D. J., & Danhof, M. (2002). Correlation between midazolam and lignocaine pharmacokinetics and MEGX formation in healthy volunteers. *British journal of clinical pharmacology*, 53(2), 133-139.

Zimmermann 1996 Zimmermann, T., Yeates, R. A., Laufen, H., Scharpf, F., Leitold, M., & Wildfeuer, A. (1996). Influence of the antibiotics erythromycin and azithromycin on the pharmacokinetics and pharmacodynamics of midazolam. *Arzneimittel-Forschung*, 46(2), 213-217.

Erythromycin-Triazolam-DDI

Greenblatt 1998 Greenblatt, D. J., von Moltke, L. L., Harmatz, J. S., Counihan, M., Graf, J. A., Durol, A. L. B., ... & Shader, R. I. (1998). Inhibition of triazolam clearance by macrolide antimicrobial agents: in vitro correlates and dynamic consequences. *Clinical Pharmacology & Therapeutics*, 64(3), 278-285.

Phillips 1986 Phillips, J. P., Antal, E. J., & Smith, R. B. (1986). A pharmacokinetic drug interaction between erythromycin and triazolam. *Journal of clinical psychopharmacology*, 6(5), 297-299.

Fluconazole-Alfentanil-DDI

Palkama 1998 Palkama, V. J., Isohanni, M. H., Neuvonen, P. J., & Olkkola, K. T. (1998). The effect of intravenous and oral fluconazole on the pharmacokinetics and pharmacodynamics of intravenous alfentanil. *Anesthesia & Analgesia*, 87(1), 190-194.

Fluconazole-Midazolam-DDI

Ahonen 1997 Ahonen, J., Olkkola, K. T., & Neuvonen, P. J. (1997). Effect of route of administration of fluconazole on the interaction between fluconazole and midazolam. *European journal of clinical pharmacology*, 51(5), 415-419.

Olkola 1996 Olkkola, K. T., Ahonen, J., & Neuvonen, P. J. (1996). The effect of the systemic antimycotics, itraconazole and fluconazole, on the pharmacokinetics and pharmacodynamics of intravenous and oral midazolam. *Anesthesia & Analgesia*, 82(3), 511-516.

Fluconazole-Triazolam-DDI

Varhe 1996 Varhe, A., Olkkola, K. T., & Neuvonen, P. J. (1996). Effect of fluconazole dose on the extent of fluconazole-triazolam interaction. *British journal of clinical pharmacology*, 42(4), 465-470.

Fluvoxamine-Alprazolam-DDI

Fleishaker 1994 Fleishaker, J. C., & Hulst, L. K. (1994). A pharmacokinetic and pharmacodynamic evaluation of the combined administration of alprazolam and fluvoxamine. *European journal of clinical pharmacology*, 46(1), 35-39.

Fluvoxamine-Midazolam-DDI

Kashuba 1998 Kashuba AD1, Nafziger AN, Kearns GL, Leeder JS, Gotschall R, Rocci ML Jr, Kulawy RW, Beck DJ, Bertino JS Jr. Effect of fluvoxamine therapy on the activities of CYP1A2, CYP2D6, and CYP3A as determined by phenotyping. *Clin Pharmacol Ther*. 1998 Sep;64(3):257-68.

Lam 2003 Lam YW1, Alfaro CL, Ereshefsky L, Miller M. Pharmacokinetic and pharmacodynamic interactions of oral midazolam with ketoconazole, fluoxetine, fluvoxamine, and nefazodone. *J Clin Pharmacol.* 2003 Nov;43(11):1274-82.

Itraconazole-Alprazolam-DDI

Yasui 1998 Yasui N, Kondo T, Otani K, Furukori H, Kaneko S, Ohkubo T, Nagasaki T, Sugawara K. Effect of itraconazole on the single oral dose pharmacokinetics and pharmacodynamics of alprazolam. *Psychopharmacology (Berl).* 1998 Oct;139(3):269-73.

Itraconazole-Midazolam-DDI

Ahonen 1995 Ahonen J, Olkkola KT, Neuvonen PJ. Effect of itraconazole and terbinafine on the pharmacokinetics and pharmacodynamics of midazolam in healthy volunteers. *Br J Clin Pharmacol.* 1995 Sep;40(3):270-2.

Backman 1998 Backman JT, Kivistö KT, Olkkola KT, Neuvonen PJ. The area under the plasma concentration-time curve for oral midazolam is 400-fold larger during treatment with itraconazole than with rifampicin. *Eur J Clin Pharmacol.* 1998 Mar;54(1):53-8.

Olkkola 1994 Olkkola KT, Backman JT, Neuvonen PJ. Midazolam should be avoided in patients receiving the systemic antimycotics ketoconazole or itraconazole. *Clin Pharmacol Ther.* 1994 May;55(5):481-5.

Olkkola 1996 Olkkola KT, Ahonen J, Neuvonen PJ. The effects of the systemic antimycotics, itraconazole and fluconazole, on the pharmacokinetics and pharmacodynamics of intravenous and oral midazolam. *Anesth Analg.* 1996 Mar;82(3):511-6.

Pruksaritanont 2017 Prueksaritanont T, Tatosian DA, Chu X, Railkar R, Evers R, Chavez-Eng C, Lutz R, Zeng W, Yabut J, Chan GH, Cai X, Latham AH, Hehman J, Stypinski D, Brejda J, Zhou C, Thornton B, Bateman KP, Fraser I, Stoch SA. Validation of a microdose probe drug cocktail for clinical drug interaction assessments for drug transporters and CYP3A. *Clin Pharmacol Ther.* 2017 Apr;101(4):519-530.

Templeton 2010 Templeton I, Peng CC, Thummel KE, Davis C, Kunze KL, Isoherranen N. Accurate prediction of dose-dependent CYP3A4 inhibition by itraconazole and its metabolites from in vitro inhibition data. *Clin Pharmacol Ther.* 2010 Oct;88(4):499-505.

Yu 2004 Yu KS, Cho JY, Jang IJ, Hong KS, Chung JY, Kim JR, Lim HS, Oh DS, Yi SY, Liu KH, Shin JG, Shin SG. Effect of the CYP3A5 genotype on the pharmacokinetics of intravenous midazolam during inhibited and induced metabolic states. *Clin Pharmacol Ther.* 2004 Aug;76(2):104-12.

Itraconazole-Triazolam-DDI

Neuvonen 1996 Neuvonen PJ, Varhe A, Olkkola KT. The effect of ingestion time interval on the interaction between itraconazole and triazolam. *Clin Pharmacol Ther.* 1996 Sep;60(3):326-31.

Varhe 1994 Varhe A, Olkkola KT, Neuvonen PJ. Oral triazolam is potentially hazardous to patients receiving systemic antimycotics ketoconazole or itraconazole. *Clin Pharmacol Ther.* 1994 Dec;56(6 Pt 1):601-7.

Rifampicin-Alfentanil-DDI

Kharasch 1997 Kharasch ED, Russell M, Mautz D, Thummel KE, Kunze KL, Bowdle A, Cox K. The role of cytochrome P450 3A4 in alfentanil clearance. Implications for interindividual variability in disposition and perioperative drug interactions. *Anesthesiology*. 1997 Jul;87(1):36-50.

Kharasch 2004 Kharasch ED, Walker A, Hoffer C, Sheffels P. Intravenous and oral alfentanil as in vivo probes for hepatic and first-pass cytochrome P450 3A activity: noninvasive assessment by use of pupillary miosis. *Clin Pharmacol Ther*. 2004 Nov;76(5):452-66.

Kharasch 2011 Kharasch ED, Francis A, London A, Frey K, Kim T, Blood J. Sensitivity of intravenous and oral alfentanil and pupillary miosis as minimal and noninvasive probes for hepatic and first-pass CYP3A induction. *Clin Pharmacol Ther*. 2011 Jul;90(1):100-8.

Kharasch 2011b Kharasch ED, Vangveravong S, Buck N, London A, Kim T, Blood J, Mach RH. Concurrent assessment of hepatic and intestinal cytochrome P450 3A activities using deuterated alfentanil. *Clin Pharmacol Ther*. 2011 Apr;89(4):562-70.

Phimmasone 2001 Phimmasone S, Kharasch ED. A pilot evaluation of alfentanil-induced miosis as a noninvasive probe for hepatic cytochrome P450 3A4 (CYP3A4) activity in humans. *Clin Pharmacol Ther*. 2001 Dec;70(6):505-17.

Rifampicin-Alprazolam-DDI

Gashaw 2003 Gashaw, I., Kirchheimer, J., Goldammer, M., Bauer, S., Seidemann, J., Zoller, K., ... & Brockmöller, J. (2003). Cytochrome p450 3A4 messenger ribonucleic acid induction by rifampin in human peripheral blood mononuclear cells: correlation with alprazolam pharmacokinetics. *Clinical Pharmacology & Therapeutics*, 74(5), 448-457.

Schmider 1999 Schmider, J., Brockmöller, J., Arold, G., Bauer, S., & Roots, I. (1999). Simultaneous assessment of CYP3A4 and CYP1A2 activity in vivo with alprazolam and caffeine. *Pharmacogenetics*, 9(6), 725-734.

Rifampicin-Midazolam-DDI

Backman 1996 Backman JT, Olkkola KT, Neuvonen PJ. Rifampin drastically reduces plasma concentrations and effects of oral midazolam. *Clin Pharmacol Ther*. 1996 Jan;59(1):7-13.

Backman 1998 Backman JT, Kivistö KT, Olkkola KT, Neuvonen PJ. The area under the plasma concentration-time curve for oral midazolam is 400-fold larger during treatment with itraconazole than with rifampicin. *Eur J Clin Pharmacol*. 1998 Mar;54(1):53-8.

Björkhem-Bergman 2013 Björkhem-Bergman L, Bäckström T, Nylén H, Rönquist-Nii Y, Bredberg E, Andersson TB, Bertilsson L, Diczfalusy U. Comparison of endogenous 4β-hydroxycholesterol with midazolam as markers for CYP3A4 induction by rifampicin. *Drug Metab Dispos*. 2013 Aug;41(8):1488-93.

Chattopadhyay 2018 Chattopadhyay N, Kanacher T, Casjens M, Frechen S, Ligges S, Zimmermann T, Rottmann A, Ploeger B, Höchel J, Schultze-Mosgau MH. CYP3A4-mediated effects of rifampicin on the pharmacokinetics of vilaprisan and its UGT1A1-mediated effects on bilirubin glucuronidation in humans. *Br J Clin Pharmacol*. 2018 Dec;84(12):2857-2866.

Chung 2006 Chung E, Nafziger AN, Kazierad DJ, Bertino JS Jr. Comparison of midazolam and simvastatin as cytochrome P450 3A probes. *Clin Pharmacol Ther*. 2006 Apr;79(4):350-61.

Eap 2004 Eap CB, Buclin T, Cucchia G, Zullino D, Hustert E, Bleiber G, Golay KP, Aubert AC, Baumann P, Telenti A, Kerb R. Oral administration of a low dose of midazolam (75 microg) as an in vivo probe for CYP3A activity. *Eur J Clin Pharmacol.* 2004 Jun;60(4):237-46.

Gorski 2003 Gorski JC, Vannaprasaht S, Hamman MA, Ambrosius WT, Bruce MA, Haehner-Daniels B, Hall SD. The effect of age, sex, and rifampin administration on intestinal and hepatic cytochrome P450 3A activity. *Clin Pharmacol Ther.* 2003 Sep;74(3):275-87.

Gurley 2006 Gurley B, Hubbard MA, Williams DK, Thaden J, Tong Y, Gentry WB, Breen P, Carrier DJ, Cheboyina S. Assessing the clinical significance of botanical supplementation on human cytochrome P450 3A activity: comparison of a milk thistle and black cohosh product to rifampin and clarithromycin. *J Clin Pharmacol.* 2006 Feb;46(2):201-13.

Gurley 2008a Gurley BJ, Swain A, Hubbard MA, Hartsfield F, Thaden J, Williams DK, Gentry WB, Tong Y. Supplementation with goldenseal (*Hydrastis canadensis*), but not kava kava (*Piper methysticum*), inhibits human CYP3A activity in vivo. *Clin Pharmacol Ther.* 2008 Jan;83(1):61-9.

Kharasch 1997 Kharasch ED, Russell M, Mautz D, Thummel KE, Kunze KL, Bowdle A, Cox K. The role of cytochrome P450 3A4 in alfentanil clearance. Implications for interindividual variability in disposition and perioperative drug interactions. *Anesthesiology.* 1997 Jul;87(1):36-50.

Kharasch 2004 Kharasch ED, Walker A, Hoffer C, Sheffels P. Intravenous and oral alfentanil as in vivo probes for hepatic and first-pass cytochrome P450 3A activity: noninvasive assessment by use of pupillary miosis. *Clin Pharmacol Ther.* 2004 Nov;76(5):452-66.

Kharasch 2011 Kharasch ED, Francis A, London A, Frey K, Kim T, Blood J. Sensitivity of intravenous and oral alfentanil and pupillary miosis as minimal and noninvasive probes for hepatic and first-pass CYP3A induction. *Clin Pharmacol Ther.* 2011 Jul;90(1):100-8.

Kim 2018 Kim B, Lee J, Shin KH, Lee S, Yu KS, Jang IJ, Cho JY. Identification of ω - or (ω -1)-Hydroxylated Medium-Chain Acylcarnitines as Novel Urinary Biomarkers for CYP3A Activity. *Clin Pharmacol Ther.* 2018 May;103(5):879-887.

Link 2008 Link B, Haschke M, Grignaschi N, Bodmer M, Aschmann YZ, Wenk M, Krähenbühl S. Pharmacokinetics of intravenous and oral midazolam in plasma and saliva in humans: usefulness of saliva as matrix for CYP3A phenotyping. *Br J Clin Pharmacol.* 2008 Oct;66(4):473-84.

Lutz 2018 Lutz JD, Kirby BJ, Wang L, Song Q, Ling J, Massetto B, Worth A, Kearney BP, Mathias A. Cytochrome P450 3A Induction Predicts P-glycoprotein Induction; Part 1: Establishing Induction Relationships Using Ascending Dose Rifampin. *Clin Pharmacol Ther.* 2018 Dec;104(6):1182-1190.

Phimmasone 2001 Phimmasone S, Kharasch ED. A pilot evaluation of alfentanil-induced miosis as a noninvasive probe for hepatic cytochrome P450 3A4 (CYP3A4) activity in humans. *Clin Pharmacol Ther.* 2001 Dec;70(6):505-17.

Pruksaritanont 2017 Prueksaritanont T, Tatosian DA, Chu X, Railkar R, Evers R, Chavez-Eng C, Lutz R, Zeng W, Yabut J, Chan GH, Cai X, Latham AH, Hehman J, Stypinski D, Brejda J, Zhou C, Thornton B, Bateman KP, Fraser I, Stoch SA. Validation of a microdose probe drug cocktail for clinical drug interaction assessments for drug transporters and CYP3A. *Clin Pharmacol Ther.* 2017 Apr;101(4):519-530.

Reitman 2011 Reitman ML, Chu X, Cai X, Yabut J, Venkatasubramanian R, Zajic S, Stone JA, Ding Y, Witter R, Gibson C, Roupe K, Evers R, Wagner JA, Stoch A. Rifampin's acute inhibitory and chronic inductive drug interactions: experimental and model-based approaches to drug-drug interaction trial design. *Clin Pharmacol Ther.* 2011 Feb;89(2):234-42.

Shin 2013 Shin KH, Choi MH, Lim KS, Yu KS, Jang IJ, Cho JY. Evaluation of endogenous metabolic markers of hepatic CYP3A activity using metabolic profiling and midazolam clearance. Clin Pharmacol Ther. 2013 Nov;94(5):601-9.

Shin 2016 Shin KH, Ahn LY, Choi MH, Moon JY, Lee J, Jang IJ, Yu KS, Cho JY. Urinary 6 β -Hydroxycortisol/Cortisol Ratio Most Highly Correlates With Midazolam Clearance Under Hepatic CYP3A Inhibition and Induction in Females: A Pharmacometabolomics Approach. AAPS J. 2016 Sep;18(5):1254-1261.

Szalat 2007 Szalat A, Gershkovich P, Ben-Ari A, Shaish A, Liberman Y, Boutboul E, Gotkine M, Hoffman A, Harats D, Leitersdorf E, Meiner V. Rifampicin-induced CYP3A4 activation in CTX patients cannot replace chenodeoxycholic acid treatment. Biochim Biophys Acta. 2007 Jul;1771(7):839-44.

van Dyk 2018 van Dyk M, Marshall JC, Sorich MJ, Wood LS, Rowland A. Assessment of inter-racial variability in CYP3A4 activity and inducibility among healthy adult males of Caucasian and South Asian ancestries. Eur J Clin Pharmacol. 2018 Jul;74(7):913-920.

Wiesinger 2020 Wiesinger H, Klein S, Rottmann A, Nowotn B, Riecke K, Gashaw I, Brudny-Klöppel M, Fricke R, Höchel J, Friedrich C. The effects of weak and strong CYP3A induction by rifampicin on the pharmacokinetics of five progestins and ethinylestradiol compared to midazolam. Clin Pharmacol Ther. 2020 Apr 10.

Yu 2004 Yu KS, Cho JY, Jang IJ, Hong KS, Chung JY, Kim JR, Lim HS, Oh DS, Yi SY, Liu KH, Shin JG, Shin SG. Effect of the CYP3A5 genotype on the pharmacokinetics of intravenous midazolam during inhibited and induced metabolic states. Clin Pharmacol Ther. 2004 Aug;76(2):104-12.

Rifampicin-Triazolam-DDI

Villikka 1997 Villikka K, Kivistö KT, Backman JT, Olkkola KT, & Neuvonen PJ. Triazolam is ineffective in patients taking rifampin. Clin Pharmacol Ther. 1997 Jan;61(1):8-14.

Rifampicin-Verapamil-DDI

Barbarash 1988 Barbarash RA, Bauman JL, Fischer JH, Kondos GT, Batenhorst RL. Near-total reduction in verapamil bioavailability by rifampin. Electrocardiographic correlates. Chest. 1988 Nov;94(5):954-9.

Verapamil-Midazolam-DDI

Backman 1994 Backman JT, Olkkola KT, Aranko K, Himberg JJ, Neuvonen PJ. Dose of midazolam should be reduced during diltiazem and verapamil treatments. Br J Clin Pharmacol. 1994 Mar;37(3):221-5.

Wang 2005 Wang Y, Jin Y, Hilligoss JK, Ho H, Hamman MA, Hu Z, Gorski JD, Hall SD. Effect of CYP3A5 genotype on the extent of CYP3A inhibition by verapamil. Clin Pharmacol Ther. 2005; 77(2):P3.

5 Appendix

5.1 Open Systems Pharmacology Suite (OSPS) Introduction

Open Systems Pharmacology Suite (OSP suite) is a tool for PBPK modeling and simulation of drugs in laboratory animals and humans. PK-Sim® and MoBi® are part of the OSP suite [1]. PK-Sim® is based on a generic PBPK-model with 18 organs and tissues. One of the main assumptions is that all compartments are well-stirred. Represented organs/tissues include arterial and venous blood, adipose tissue (separable adipose, excluding yellow marrow), brain, lung, bone (including yellow marrow), gonads, heart, kidneys, large intestine, liver, muscle, portal vein, pancreas, skin, small intestine, spleen and stomach, as shown in [Figure Appendix-1](#).

Each organ consists of four sub-compartments namely the plasma, blood cells (which together build the vascular space), interstitial space, and cellular space. Distribution between the plasma and blood cells as well as between the interstitial and cellular compartments can be permeability-limited. In the brain, the permeation barrier is located between the vascular and the interstitial space. PK-Sim® estimates model parameters (intestinal permeability [2] organ partition coefficients (tissue-to-plasma partition coefficients) [3,4], and permeabilities) from physico-chemical properties of compounds (molecular weight, pKa, acid/base properties) and the composition of each tissue compartment (lipids, water and proteins). Partition coefficients can be calculated using a variety of methods available in PK-Sim®, for example the internal PK-Sim® method [3,4] or that of Rodgers and Rowland [5-7].

Physiological databases included in the software incorporate the dependencies of organ composition, organ weights, organ blood flows and gastrointestinal parameters (gastrointestinal length, radius of each section, intestinal surface area, gastrointestinal transit times, and pH in different intestinal segments [2]), with the user-defined body weight and height and ethnicity of the individual [8]. Thereby, PK Sim® allows generating realistic virtual populations. For a detailed description of the PBPK model structure implemented in PK Sim®, see Willmann et al. [2,4,8,9] or the OSP Suite homepage (<https://docs.open-systems-pharmacology.org/mechanistic-modeling-of-pharmacokinetics-and-dynamics/modeling-concepts>).

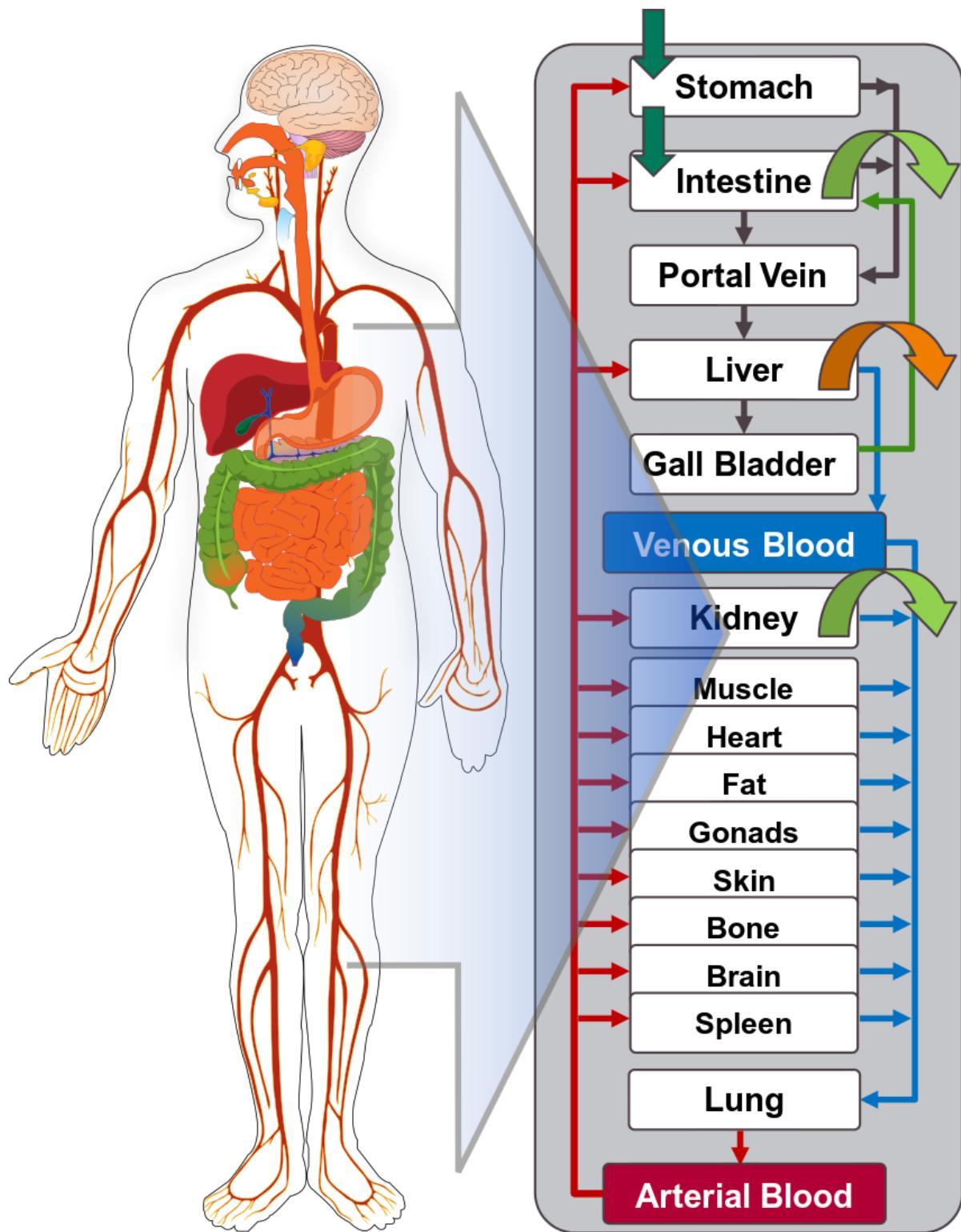


Figure Appendix-1: Structure of the Whole Body PBPK Model integrated in PK-Sim®

References for OSPS introduction

- [1] www.open-systems-pharmacology.org
- [2] Willmann S, Schmitt W, Keldenich J, Lippert J, Dressman JB. A physiological model for the estimation of the fraction dose absorbed in humans. *J Med Chem*. 2004 Jul 29;47(16):4022-31.
- [3] Haerter MW, K.J., Schmitt W, *Estimation of physicochemical and ADME parameters* . , in *Handbook of Combinatorial Chemistry: Drugs, Catalysts, Materials*, H.W. Nicolaou KC HR, Editor. 2002, Wiley VCH Verlag GmbH: Weinheim, Germany. p. 743-60.

- [4] Willmann S, Lippert J, Schmitt W. From physicochemistry to absorption and distribution: predictive mechanistic modelling and computational tools. *Expert Opin Drug Metab Toxicol*. 2005 Jun;1(1):159-68.
- [5] Rodgers, T, D. Leahy, and M. Rowland. Physiologically based pharmacokinetic modeling 1: predicting the tissue distribution of moderate-to-strong bases. *J Pharm Sci*. 2005 Jun;94(6):1259-76.
- [6] Rodgers T, Rowland M. Physiologically based pharmacokinetic modelling 2: predicting the tissue distribution of acids, very weak bases, neutrals and zwitterions. *J Pharm Sci*. 2006 Jun;95(6):1238-57.
- [7] Rodgers T, Rowland M. Mechanistic approaches to volume of distribution predictions: understanding the processes. *Pharm Res*. 2007 May;24(5):918-33.
- [8] Willmann S, Höhn K, Edginton A, Sevestre M, Solodenko J, Weiss W, Lippert J, Schmitt W. Development of a physiology-based whole-body population model for assessing the influence of individual variability on the pharmacokinetics of drugs. *J Pharmacokinet Pharmacodyn*. 2007 Jun;34(3):401-31.
- [9] Willmann S, Lippert J, Sevestre M, Solodenko J, Fois F, Schmitt W. PK-Sim®: a physiologically based pharmacokinetic ‘whole-body’ model. *Biosilico* 2003.1(4):121-24.

5.2 Mathematical Implementation of Drug-Drug Interactions

DDI modeling: Competitive inhibition

A detailed representation of the mathematical implementation of competitive enzyme inhibition can be found in the OSP manual (<https://docs.open-systems-pharmacology.org/working-with-pk-sim/pk-sim-documentation/pk-sim-compounds-defining-inhibition-induction-processes#competitive-inhibition-simple-setting-with-one-inhibitor>).

DDI modeling: Mechanism-based inhibition

A detailed representation of the mathematical implementation of mechanism-based enzyme inhibition can be found in the OSP manual (<https://docs.open-systems-pharmacology.org/working-with-pk-sim/pk-sim-documentation/pk-sim-compounds-defining-inhibition-induction-processes#irreversible-inhibition>).

DDI modeling: Induction

A detailed representation of the mathematical implementation of enzyme induction can be found in the OSP manual (<https://docs.open-systems-pharmacology.org/working-with-pk-sim/pk-sim-documentation/pk-sim-compounds-defining-inhibition-induction-processes#enzyme-induction>).

5.3 Automatic (re)-qualification workflow

Open Systems Pharmacology (<https://www.open-systems-pharmacology.org/>) provides a dynamic landscape of model repositories and a database of observed clinical data. Additionally, a technical framework to assess confidence of a specific intended use has been developed (qualification runner and reporting engine). This framework allows for an automatic (re)-qualification workflow of the OSP suite, comprising the following steps **Figure Appendix-2**:

- PBPK model development and verification with observed data,
- Qualification plan generation,
- Qualification plan execution,
- Qualification report generation.

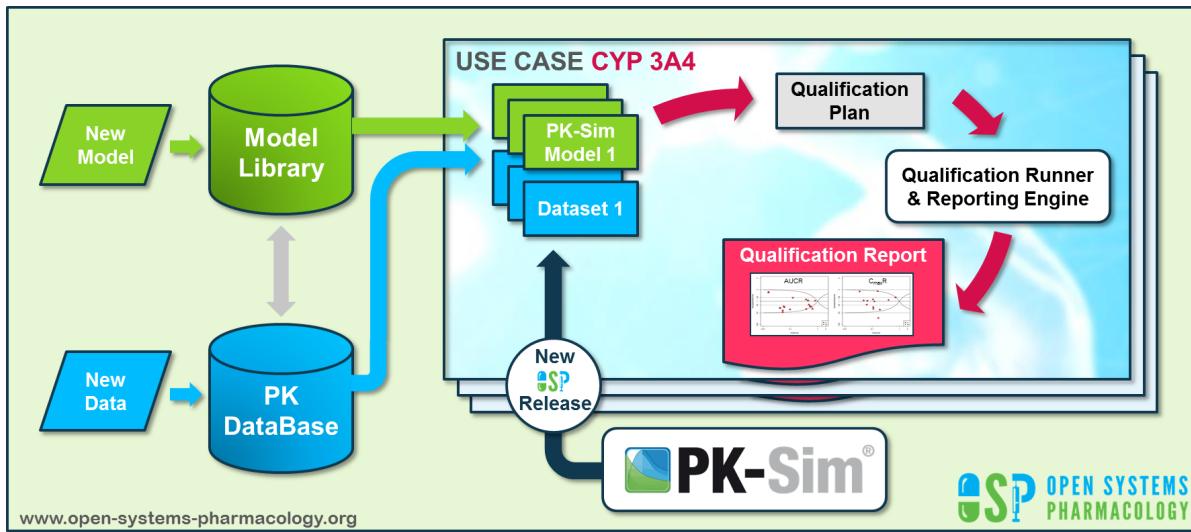


Figure Appendix-2: OSP suite automatic (re)-qualification workflow

In a first step, the respective qualification scenario is saved in a special qualification repository on OSP GitHub (<https://github.com/Open-Systems-Pharmacology/>). This qualification scenario repository contains a detailed qualification plan that links and combines respective models and data to address the use case that shall be qualified. Therefore, the qualification plan consists of:

- PK-Sim project files,
- Additional model building steps (if applicable),
- Description of potential cross-dependencies between PK-Sim project files (if applicable),
- Observed data (needed for model development and verification),
- Qualification scenario description text modules
- Detailed report settings to describe the generation of charts and qualification measures.

PK-Sim projects, observed data sets, and qualification scenario text modules are deposited in distinct repositories and are referenced by the qualification plan ([Figure Appendix-3](#)).

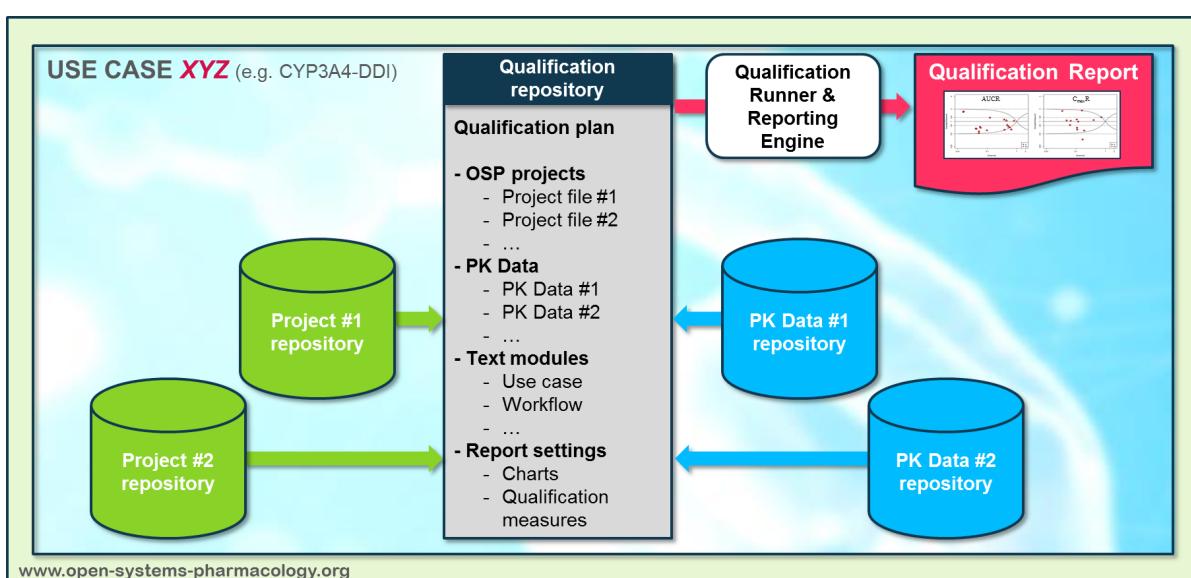


Figure Appendix-3: Qualification scenario repository landscape on GitHub

In a second step the qualification runner (<https://github.com/Open-Systems-Pharmacology/QualificationRunner>) processes the qualification plan, i.e. all project parts are exported and prepared for the reporting engine (<https://github.com/Open-Systems-Pharmacology/Reporting-Engine>). The reporting engine provides a validated environment (implemented in R) for model execution and finally generates the qualification report. This report contains the evaluation of the individual PBPK models with observed data (i.e. standard goodness of fit plots, visual predictive checks) and a comprehensive qualification of the specific use case assessing the predictive performance of the OSP suite by means of a predefined set of qualification measures and charts.

The automated execution of the described workflow can be triggered to assess re-qualification in case new data, changes in model structure or parameterization, or new OSP suite releases arise.