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Pharmacometrics

CLINICAL TRIAL SIMULATION
DESIGN & ANALYSIS

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ANALYSIS

- Descriptive
- Comparison
 - » Means
 - » Proportions
- Regression
 - » Linear
 - » Non-linear

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Descriptive Statistics

- Mean
- Standard Deviation
- Standard Error
- etc

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Means

- Two Samples
 - » t-test
- ANOVA
 - » one factor
 - » two factor
 - » etc
- Parametric/Non-Parametric
- Repeated Measures

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Proportions

- Chi-square

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Regression

- Correlation
- Linear regression
 - » simple
 - » multiple
- Non-linear regression
 - » individual
 - » population

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Regression

- Parameters and Models
 - » Test hypotheses with different models
 - » Estimate parameters

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Non-Linear Regression Methods

- Individual
 - » WINNONLIN
 - » ADAPT
 - » KINETICA
- Population
 - » NONMEM
 - » NPML
 - » MONOLIX
 - » WinBUGS

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SIMULATION

- Visualise the expected results
- Plan data layout
- Rehearse analysis method
- Optimise design

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Monte-Carlo Simulation

- Developed for atomic bomb research
- Based on using random numbers to generate simulated data
- Very powerful tool for modern statistics

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Simulation Methods

- General
 - » Excel
 - » Berkeley Madonna
- Clinical Trials
 - » RIDO
 - » Pharsight

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Simulation Models

- Covariate Distribution
 - » Variability and covariance
 - » Predicts Subject characteristics (age, weight, sex, renal function)
- Input-Output
 - » Structural, fixed and random effects
 - » Predicts protocol observations
- Execution
 - » Deviations from nominal protocol
 - » Predicts actual observations

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Exposure-Response Relationship

- Exposure
 - » Dose
 - » Area under the Conc-Time Curve
 - » Concentration(Time)
- Response
 - » Biomarker
 - » Clinical Outcome

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Clinical Trial Simulation (CTS) Process

1. Predict time course of response in patient
2. Add variability (subject, execution)
3. Analyse single clinical trial
4. Replicate Steps 1-3 multiple times (100+)
5. Meta-analysis of multiple replicates
6. Evaluate design performance (e.g. power)
7. Replicate Steps 4-6 over design space
8. Construct design-performance surface

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What Questions does CTS help to Answer?

- **Confirming Trials**
 - » Does the drug work?
 - » YES/NO Answer
 - » **Power**
- **Learning Trials**
 - » How big an effect?
 - » Effect Size Estimates
 - » **Bias and Precision**

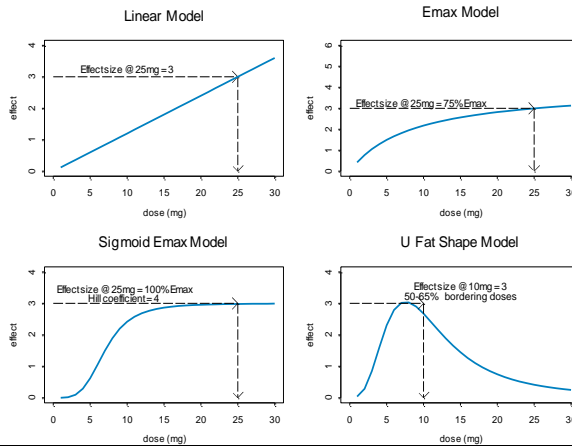
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Why Use Simulation for Exposure Response?

- **Between subject variability**
 - » Covariate Distribution model
- **Complex time varying responses**
 - » Input Output model
- **Nominal protocol never happens**
 - » Execution model

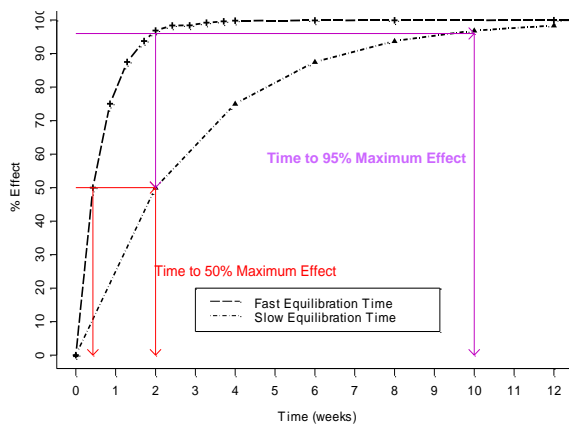
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Exposure Response Shape



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Speed of Onset



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Parameter Sensitivity

- Always uncertainty about key parameters
- Consider two cases compared to existing therapy:
 - » **Standard**: New drug similar Emax
 - » **Super**: New drug has greater Emax

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Does The Drug Work?

Power to Detect One or More Significant Dose Levels

Assumption	No Effect	Lin	Emax	SEmax	Ushape
Slow Std	1	63	53	80	21
Fast Std		97	97	100	69
Slow Super		97	98	100	62
Fast Super		100	100	100	100

- Sensitive to magnitude of effect
- Poor power for slow onset
- Poor power for U Shape DR pattern
- Type 1 error (no effect column) is acceptable (1%)

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How Big an Effect?

DR Pattern	Best effect dose	Standard		Super	
		slow onset	fast onset	slow onset	fast onset
Linear	25	45	98	46	98
SEMax	25	68	103	68	104
Emax	25	49	91	50	92
Ushape	10	39	99	41	100

% of true value @ 2 weeks for best effect dose

- Slow onset has **biased** (under) estimate of true effect

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Dose, Concentration or AUC?

- Why use Dose?
 - » Direct translation to prescription
- Why not use Dose?
 - » Ignores individual differences

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Dose, Concentration or AUC?

- Why use Concentration?
 - » Learn about time course
 - » Account for individual PK differences
- Why not use Concentration?
 - » May be hard to measure
 - » Extra resources for PK analysis

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Dose, Concentration or AUC?

- Why use AUC?
 - » Account for individual PK differences
- Why not use AUC?
 - » May be hard to measure
 - » Extra resources for PK analysis
 - » Ignores time course

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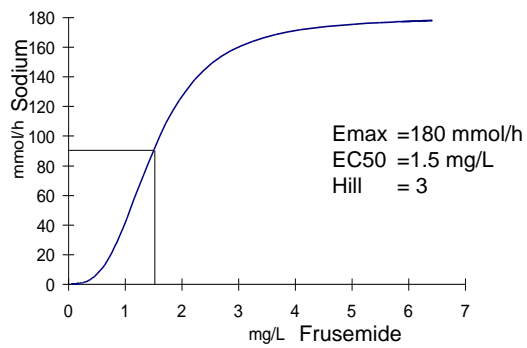
When is Time Course Important?

- Dose vs AUC is linear
- C vs Effect is non-linear
- Outcome is related to cumulative effect

Almost all drugs!

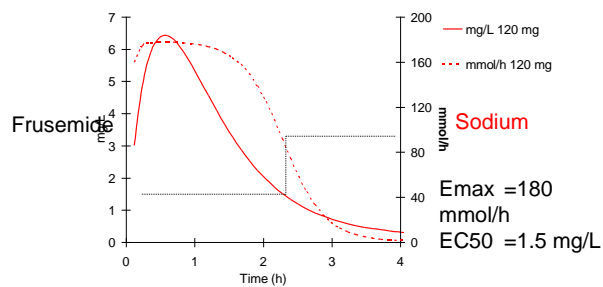
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Frusemide Diuretic Effect

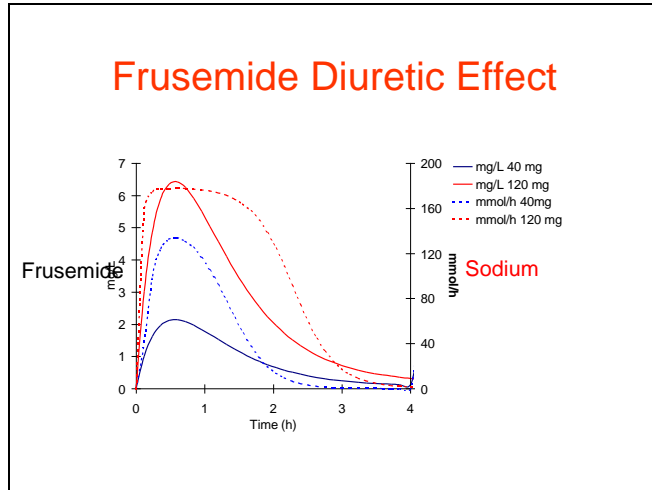


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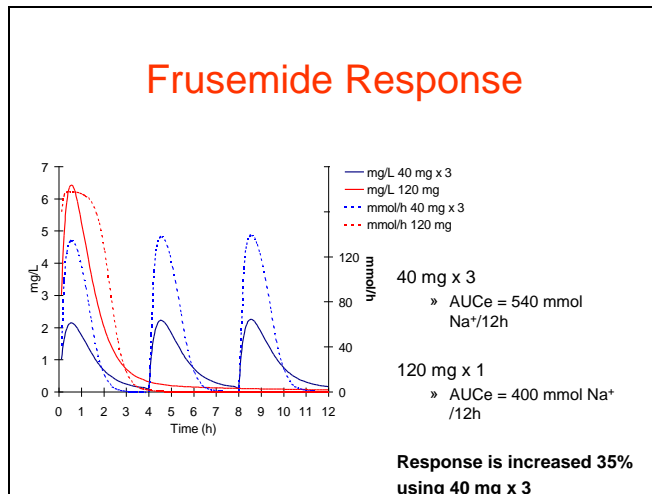
Frusemide Diuretic Effect



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Schedule Dependence

- Response is NOT proportional to cumulative diuretic dose or AUC
- Response IS proportional to cumulative diuretic effect or AUCe
- Phenomenon is known as
 - » “Schedule Dependence”

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Anti-Cancer Agents

- Alkylating agents
 - » covalent binding to various cell components
- DNA binding agents
 - » interrupt cell division

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Anti-Cancer Agents

- Action
 - » Irreversible binding to cell structure
- Effect
 - » Block of cell division/cell death
 - » Slowing or reversal of tumour growth
- Response
 - » Decreased morbidity (e.g. Pain)
 - » Postponement of death

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Anti-Cancer Agents

- Schedule Dependence is common
- Large intermittent doses are often more toxic and less effective than smaller repeated doses
- Response is related to cumulative dose as well as Schedule
- AUC may be used to guide individual treatment

How Should Anticancer Drug Dose be Optimized?

- Schedule dependence is well known
Outcome not related to current drug effect
- AUC approaches ignore schedule
Throwing away time
- Simulate to **learn** to **optimize** the dose
*Rather than misguided empiricism using
AUC*