Being an Effective Consumer of Preclinical Research

THE SAFETY PERSPECTIVE

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Disclosures

- Dietrich Haubenberger is a full-time employee of Neurocrine Biosciences, Inc.

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Questions to be answered with pre-clinical data:

- Is it safe to put drug candidate into humans?
- What is an safe dose for human clinical trials?
  - Starting dose
  - End dose
- What are dose-limiting toxicities?
  - Therefore: what should be monitored in clinical trials?
- What could be potential toxicities that would be difficult to monitor in clinical trials?

General principles: Non-clinical testing

- *Main goals*
  1. Identification of organ toxicity
  2. Relationship to drug exposure
  3. Determination of on- and off-target effects
  4. Potential relevance to humans
  5. Identification / qualification of safety biomarkers to monitor in clinic

- *Non-clinical safety testing regimens depend on*
  1. Type of therapeutic (small molecule, biologic, etc.)
  2. Therapeutic indication (CNS, etc.)
  3. Scope and design of first-in-human trial (treatment duration, route of administration, etc.)

Shen J, Swift B, Mamelok R, Pine S, Sinclair J, Attar M.
Design and Conduct Considerations for First-in-Human Trials. Clin Transl Sci 2018.

What should I know about my drug:

IND: FDA Form 1571

12. **CONTENTS OF APPLICATION**

This application contains the following items: *(Check all that apply)*

- ☐ 1. Form FDA 1571 *[21 CFR 312.23(a)(1)]*
- ☐ 2. Table of Contents *[21 CFR 312.23(a)(2)]*
- ☐ 3. Introductory statement *[21 CFR 312.23(a)(3)]*
- ☐ 4. General Investigational plan *[21 CFR 312.23(a)(3)]*
- ☐ 5. Investigator's brochure *[21 CFR 312.23(a)(5)]*
- ☐ 6. Protocol(s) *[21 CFR 312.23(a)(6)]*
  - ☐ a. Study protocol(s) *[21 CFR 312.23(a)(6)]*
  - ☐ b. Investigator data *[21 CFR 312.23(a)(6)(iii)(b)]* or completed Form(s) FDA 1572
  - ☐ c. Facilities data *[21 CFR 312.23(a)(6)(iii)(b)]* or completed Form(s) FDA 1572
  - ☐ d. Institutional Review Board data *[21 CFR 312.23(a)(6)(iii)(b)]* or completed Form(s) FDA 1572
- ☐ 7. Chemistry, manufacturing, and control data *[21 CFR 312.23(a)(7)]*
  - ☐ Environmental assessment or claim for exclusion *[21 CFR 312.23(a)(7)(iv)(e)]*
- ☐ 8. Pharmacology and toxicology data *[21 CFR 312.23(a)(8)]*
- ☐ 9. Previous human experience *[21 CFR 312.23(a)(9)]*
- ☐ 10. Additional information *[21 CFR 312.23(a)(10)]*

What should I know about my drug:

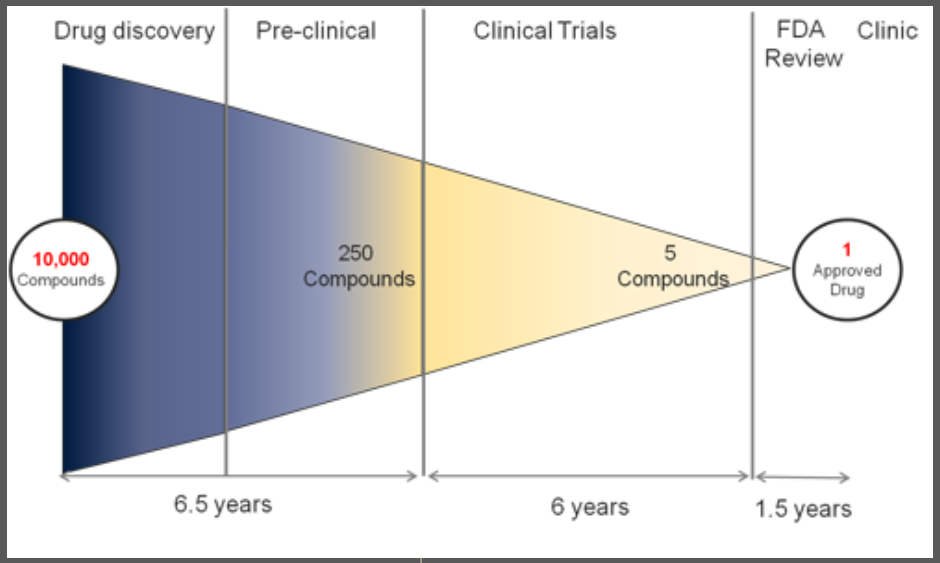
- CMC: Chemistry, Manufacturing, and Control
  - A drug product is composed of
    - Drug substance (API)
    - Excipients
    - Impurities
    - Container
  - Data on ***Identity***, ***Strength***, ***Purity***, and ***Quality*** of drug
  - Additional Information:
    - Manufacturer, Storage, Stability, etc.

What should I know about my drug:

- Pharmacology & Toxicology
  - Pharmacological effect and mechanism in animals
  - **A**bsorption, **D**istribution, **M**etabolism, **E**xcretion
  - Toxicology (acute/subacute/chronic)
  - Safety pharmacology per systems:
    - Cardiovascular, CNS, pulmonary, etc.
  - Special toxicology tests related to mode of administration
    - e.g., dermal toxicology
  - Genetic toxicology (often in vitro)

Once First-in-Human started, done with pre-clinical?

non-clinical development



CMC for Phase 1
Pharmacology
Acute Toxicology

CMC: Alternate formulations, lots, etc.
Chronic Toxicology
Pharmacology of alternate formulations
Reproductive toxicology
Addtl. safety pharmacology
...

Non-Clinical Safety for IND – the regulatory view

- **Off the shelf FDA-approved drug:**
  - *Assume* that the drug product meets animal toxicology standards for maximum approved dose and length of exposure per label.
  - If higher dose, longer duration, different formulation, or different route of administration is planned than what is approved in the label, FDA may require additional non-clinical studies.
  - Different patient population: different risk/benefit ratio and propensity for safety events
  - If combination of more than one approved drugs are given: FDA may require Drug-Drug-Interaction studies
  - CMC: if used exactly as marketed: label sufficient

Non-Clinical Safety for IND – the regulatory view

- **Investigational drug supplied by a different sponsor**
  - Obtain a letter allowing reference to another IND.
  - Ask for and make yourself familiar with the Investigator's Brochure (IB)
  - Must support the planned dose, duration, and route of administration.
- **Dietary supplement**
  - Typically not an approved drug without approved safe dose.
  - No non-clinical toxicology can be assumed.
  - If used as drug in a clinical trial: it's a drug, and must adhere to similar requirements as "regular" pharmaceuticals.
- **Investigational drug you make yourself**
  - Generally must provide full set of non-clinical pharmacology and toxicology data using you own product.

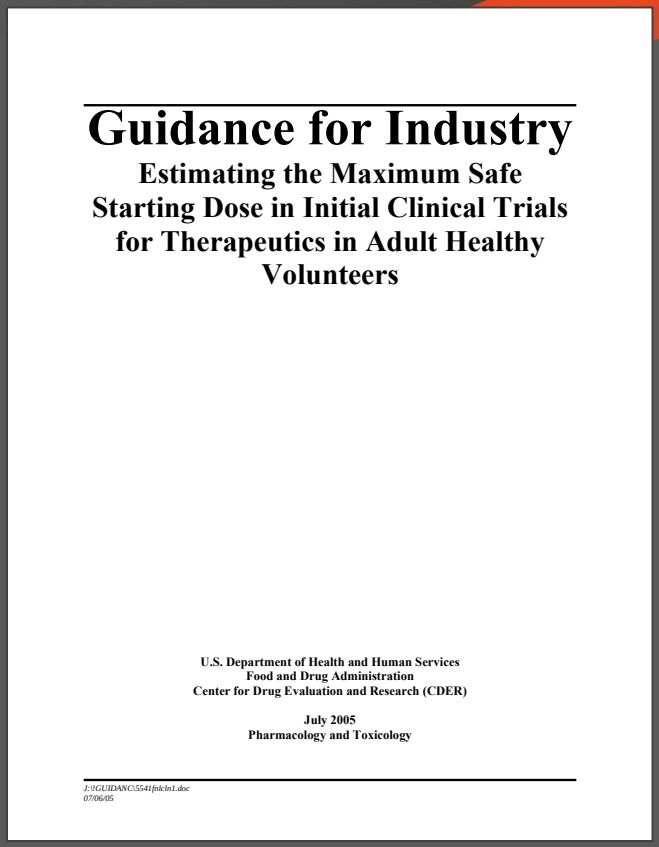
How to pick a starting dose

- *You might not need additional non-clinical information if …*
  - An FDA-approved dosing range is available (see label)
  - Data in the literature, or any other study that is available to you supports dose range, duration of exposure, and mode of administration
    - Animal studies
    - Human experience
    - ***CAVEAT*:** Reports/publications must be specific
      - N of exposed animals, humans
      - Doses, duration of exposure, mode of administration
      - Ideally: obtain data sets!

From animal to human …

- If no previous human experience, estimate ***Maximum Recommended Starting Dose (MRSD)*** using 5 steps:

1. NOAEL
2. Human Equivalence Dose
3. Species Selection
4. Safety Factor
5. Pharmacologically Active Dose



Guidance for Industry

Estimating the Maximum Safe Starting Dose in Initial Clinical Trials for Therapeutics in Adult Healthy Volunteers

U.S. Department of Health and Human Services
Food and Drug Administration
Center for Drug Evaluation and Research (CDER)

July 2005
Pharmacology and Toxicology

J:\GUIDANCE\5541fnlcln1.doc
07/06/05

http://www.fda.gov/downloads/Drugs/Guidances/UCM078932.pdf

Step 1: NOAEL

- *No Observed Adverse Effect Level*
- Definition
  - **"The highest dose level that does not produce a significant increase in adverse effects in comparison to the control group."**
  - AEs that are *biologically significant* should be considered for determination of NOAEL
- Benchmark for safety when derived from *appropriate* animal studies
- Can serve as the starting point for determining a reasonably safe starting dose of a new therapeutic in humans

Step 2: Human Equivalent Dose (HED)

- Toxic endpoints (e.g., MTD) are assumed to *scale* well between species when normalized to body surface area
- HED can be calculated using body surface area (mg/m^2) converted into mg/kg using standardized species-specific scaling factors

Table 1: Conversion of Animal Doses to Human Equivalent Doses Based on Body Surface Area

Species	To Convert Animal Dose in mg/kg to Dose in mg/m^2, Multiply by k_m	To Convert Animal Dose in mg/kg to HED[a] in mg/kg, Either:	
		Divide Animal Dose By	Multiply Animal Dose By
Human	37	---	---
Child (20 kg)[b]	25	---	---
Mouse	3	12.3	0.08
Hamster	5	7.4	0.13
Rat	6	6.2	0.16
Ferret	7	5.3	0.19
Guinea pig	8	4.6	0.22
Rabbit	12	3.1	0.32
Dog	20	1.8	0.54
Primates:			
Monkeys[c]	12	3.1	0.32
Marmoset	6	6.2	0.16
Squirrel monkey	7	5.3	0.19
Baboon	20	1.8	0.54
Micro-pig	27	1.4	0.73
Mini-pig	35	1.1	0.95

[a] Assumes 60 kg human. For species not listed or for weights outside the standard ranges, HED can be calculated from the following formula:

HED = animal dose in mg/kg x (animal weight in kg/human weight in kg)$^{0.33}$.

[b] This k_m value is provided for reference only since healthy children will rarely be volunteers for phase 1 trials.

[c] For example, cynomolgus, rhesus, and stumptail.

http://www.fda.gov/downloads/Drugs/Guidances/UCM078932.pdf

Step 3: Species selection

- If more > 1 species were studied, which HED to pick?
- Factors to consider
  - Animal model most predictive of human toxicity
  - Differences in absorption, distribution, metabolism, excretion (ADME)
  - For Biologics: does model express relevant receptors/epitopes?
- In absence of data on species relevance: choose species with *lowest* HED

Step 4: Safety Factor

- Goal: providing a margin of safety for protection of human subjects receiving the initial clinical dose
- Allows for variability in extrapolating from animal tox studies resulting
- Default safety factor: **10**
  - Practically: divide appropriate HED by 10
  - Reasons for *increasing* the safety factor: steep dose response curve, severe/irreversible toxicities, non-monitorable toxicities, toxicities without premonitory signs, animal model with limited utility, etc.
  - Reasons for *decreasing* the safety factor: therapeutic is member of well-characterized class, easily monitorable toxicities, etc.

Step 5: Pharmacologically active dose (PAD)

- Definition:
  - *The PAD is the lowest dose tested in an animal species with the intended pharmacological activity*
- Typically derived from appropriate pharmacodynamic models.
- Once MRSD is determined, compare to the HED of the PAD.
- If needed, adjust MRSD if *pharmacologic* HED is lower
- PAD might also be a more sensitive indicator of potential toxicity (e.g., vasodilators, anticoagulants, etc.)

Example

- Non-clinical toxicology studies determined a NOAEL of 15 mg/kg in dogs, 50 mg/kg in rats, and 50 mg/kg in monkeys.
- Conversion to HED
  - Division method:
    15 mg/kg (dog) / 1.8 = 8 mg/kg
    50 mg/kg (rat) / 6.2 = 8 mg/kg
    50 mg/kg (monkey) / 3.1 = 16 mg/kg
- Appropriate HED: 8 mg/kg
- Safety factor 10:
  - ***Max. recommended starting dose: 0.8 mg/kg***

Table 1: Conversion of Animal Doses to Human Equivalent Doses Based on Body Surface Area

Species	To Convert Animal Dose in mg/kg to Dose in mg/m², Multiply by k_m	To Convert Animal Dose in mg/kg to HED[a] in mg/kg, Either:	
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Limitations of the NOAEL/MRSD approach

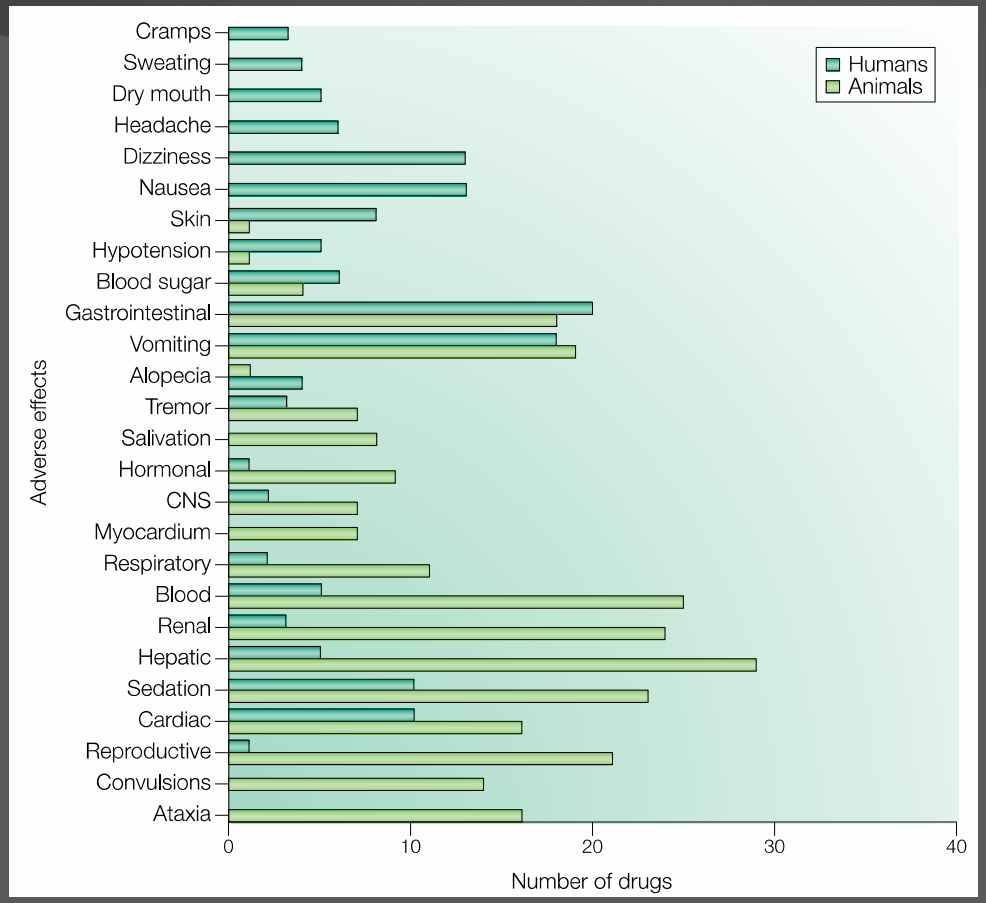
- Algorithm can be too „mechanical“
- Toxicity focused, less pharmacology-based
- Does not address dose escalation
- Does not apply to locally administered drugs
- Not fully applicable to biologics
  - Often no real NOAEL measurable
  - Alternative approach using Minimum Anticipated Biological Effect Level (MABEL)

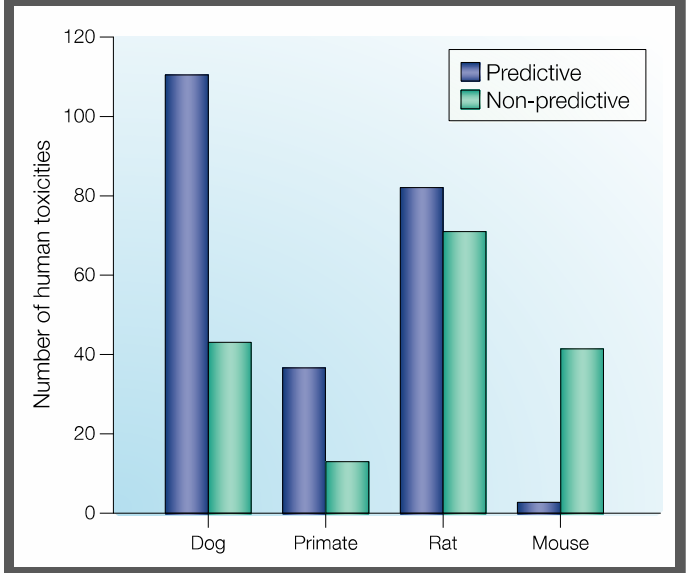
Clinical Safety Monitoring

- Non-clinical safety signals determine clinical safety monitoring
- But: be vigilent about the unknown!
  - Review from 150 compounds:
    - positive concordance rate (sensitivity) between observed animal and human toxicities is 70%
    - Therefore, 30% of human toxicities are not predicted.

Olson H, et al. Concordance of the toxicity of pharmaceuticals in humans and in animals. Regul Toxicol Pharmacol. 2000 Aug;32(1):56-67.

Toxicity prediction





Greaves P, Williams A, Eve M. First dose of potential new medicines to humans: how animals help. Nat Rev Drug Discov. 2004 Mar;3(3):226-36.

Summary

- If human data is lacking, non-clinical safety data crucial for
  - Dose selection
  - Planning of safety monitoring procedures in the clinical trial
  - Meeting regulatory requirements
- Human data may be more valuable than non-clinical data
- Non-clinical experiments are usually expensive, and time-consuming
- Usually no need to worry if compound is FDA approved and used within the confines of the label

Thank you