Considering A Bridging Strategy Driven By Patient Need and Contemporary Science

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The ‘Ethnic Drug Development and Approval Paradigm’ as I see it

- Disease differences between regions are not adequately considered in global development plans or approval guidelines.
- Ethnic diversity in a very large number of PK, PD, efficacy & safety variables makes conventional development planning difficult.
- If one accepts these thoughts, then there may be some fundamental changes in how we develop and approve drugs.
Race (Black, Asian, Caucasian) & Ethnicity (Hispanic)

• Race, ethnicity & nationality: known differences in disease and drug PK & PD
• Drug efficacy & safety related to country (e.g., French), region (EU), ethnicity, gender…
• Drugs approved both by countries and regions representing their populations
Phase 1-3 development

- Inefficient and too expensive to duplicate in each country
- Research must meet minimum global quality standards (GCP, GLP)

Country regulatory requirement for NDA approval

- Country experience required to support approval?
- Are Japanese or Chinese patients ≈ Asian patients?
- Is there a need to revise ICH5 or write a Global development guideline?
- Should regulatory dialogue on global drug development strategy occur early?
- Should simulation be encouraged to support planning (e.g., trial design)?

Pharmaceutical companies can

- Create global development plan based on known differences
- Implement learn-simulate-confirm cycle in drug development to account for global variables influencing disease, pharmacokinetics, pharmacodynamics
Outline

• Bridging need
• Bridging potential issues
• International & local bridging guidelines
  – ICH-5
  – Japan
  – China
  – U.S.
• Are current assumptions correct?
• New approach to global drug development
• Scenarios
Key Questions for Developers & Regulators
between country-ethnic differences?
NDA population sample & bridged country population?

• Disease
  • Is disease the same (e.g., mechanism, pathogenesis, progression, morbidity & mortality)?
  • Is medical practice the same (e.g., diagnostic criteria)?
  • Is disease severity the same?
  • Are co-morbidities the same?

• Pharmacology (efficacy-safety)
  • Is efficacy-safety dose-response (PK-PD) the same?
  • Is the link between biomarkers and efficacy-safety the same?

• Benefit-Risk
  • Are benefits and risks perceived the same between ethnic groups?
Issues

- Regulatory requirements are formulaic such as specifying a pharmacokinetic study + a fixed number of patients in phase 3 trials for all diseases and drug classes
- Country drug approval strategies may not account for ethnic or regional differences
- Efficient global drug development strategy balancing local patient needs and global development financial expense
- Opportunities for between country collaboration
International & local bridging guidelines

- **ICH5** (http://www.ich.org/LOB/media/MEDIA481.pdf)
  - **Premise.**
    - Development efficiency- sharing development data for regulatory decisions between regions
    - ‘Acceptability of the foreign clinical data component of the complete data package depends then upon whether it can be extrapolated to the population of the new region.’
  - **Focus.** Pharmacokinetics, pharmacodynamics, dose-response, efficacy, safety, clinical trial standards.
  - **Disease topics**
    - Endpoints for assessing treatment effectiveness
    - Medical and diagnostic definitions acceptable to the new region
  - **Recommendation.** Amend ICH5 to gain an assessment of
    - Disease differences, if any and clinical significance, if any
    - How to manage drug development if the disease difference is deemed to be clinically significant
International & local bridging guidelines
(1st approved elsewhere scenario)

- Japan
  - **Bridging experience**  (Clin Pharm Ther 87:362, 2010)
    - In 2006 2.5 year drug lag (compared to USA) sequential rather than parallel development
      - ICHE5 guideline implementation in Japan may have led to the 2.5 year lag starting ~late 90s. (Drug Info J 43:3, 2009)
        » Wanted only Japanese, not Asian patients
        » Japanese patients in every development phase
    - Lower doses in Japan (vs USA-EU) 31.2% approved new drugs 2003-7 (n=41)
  - **Global Clinical Trial recommendation 2007**
    (http://www.pmda.go.jp/english/service/pdf/notifications/0928010-e.pdf)
    - Definition. ‘A trial designed for a new drug aiming for worldwide development and approval, having multiple countries, regions, and medical institutions participating in a single clinical trial and conduct concurrently in accordance with a common clinical trial protocol.’
    - Recommend Japanese participate in dose finding studies
    - Japanese patients 15-20% of total

Clin Pharm Ther 87:714, 2010
International & local bridging guidelines (1st approved elsewhere scenario)

- Japan
- China
  - PK study-mainland
  - $\geq 100$ pairs Chinese patients-mainland
- USA
  - Case by case basis with CDER division
  - Concern when all data foreign
  - No guideline, but $\geq 25\%$ U.S. patients target
    my advice
## Height by Location
(descending male cm)

<table>
<thead>
<tr>
<th>Location</th>
<th>Male (cm)</th>
<th>Female (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>185</td>
<td>169</td>
</tr>
<tr>
<td>Sweden</td>
<td>180</td>
<td>167</td>
</tr>
<tr>
<td>Finland</td>
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<td>165</td>
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<tr>
<td>Germany</td>
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<td>165</td>
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<tr>
<td>USA</td>
<td>178</td>
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<tr>
<td>Japan</td>
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<tr>
<td>Hong Kong</td>
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<td>159</td>
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<tr>
<td>Mexico</td>
<td>167</td>
<td>155</td>
</tr>
<tr>
<td>China</td>
<td>165</td>
<td>155</td>
</tr>
<tr>
<td>Philippines</td>
<td>164</td>
<td>152</td>
</tr>
</tbody>
</table>
## Evidence for Differences

### Chronic Hepatitis B

<table>
<thead>
<tr>
<th>Criteria</th>
<th>USA, EU</th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission</td>
<td>Adult &gt; Perinatal</td>
<td>Perinatal $\geq$ Adult</td>
</tr>
<tr>
<td>Virus genotype- (predominant)</td>
<td>A</td>
<td>B, C</td>
</tr>
<tr>
<td>HIV co-infection</td>
<td>5-10%</td>
<td>20-30%</td>
</tr>
<tr>
<td>Cirrhosis risk</td>
<td></td>
<td>lower</td>
</tr>
<tr>
<td>Hepatocellular carcinoma risk</td>
<td></td>
<td>greater</td>
</tr>
<tr>
<td>Genotype Interferon alpha 2b HbeAg &amp; HbsAg seroconversion</td>
<td>A&gt;B&gt;C&gt;D</td>
<td></td>
</tr>
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</table>

## Evidence for Differences

### Lung Cancer

<table>
<thead>
<tr>
<th></th>
<th>Western</th>
<th>Asian</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficacy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- NSCLC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- EGFR Mutations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- All patients</td>
<td>7%</td>
<td>31%</td>
</tr>
<tr>
<td>- Adenocarcinoma</td>
<td>13%</td>
<td>47%</td>
</tr>
<tr>
<td>- Non-smokers</td>
<td>35%</td>
<td>56%</td>
</tr>
<tr>
<td>- Efficacy response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Erlotinib</td>
<td>10%</td>
<td>28%</td>
</tr>
<tr>
<td>- Gefitinib</td>
<td>5.5 mo MST*</td>
<td>9.5 mo MST*</td>
</tr>
<tr>
<td><strong>Toxicity (grade 3-4)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Carboplatin + paclitaxel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Neutropenia</td>
<td>6-65%</td>
<td>88%</td>
</tr>
<tr>
<td>- Febrile neutropenia</td>
<td>0-4%</td>
<td>16%</td>
</tr>
<tr>
<td>- Cisplatin + vinorelbine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Neutropenia</td>
<td>37-83%</td>
<td>88%</td>
</tr>
<tr>
<td>- Febrile neutropenia</td>
<td>1-22%</td>
<td>18%</td>
</tr>
</tbody>
</table>

★ Median Survival Time

*Br J Cancer 99:1757-62, 2008*
Evidence for Differences
Lung Cancer Stage

Data from Draco Epidemiology Study, 2008
## Evidence for Differences

### Breast Cancer

<table>
<thead>
<tr>
<th></th>
<th>Western</th>
<th>Asian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidence</td>
<td>$101/10^5$</td>
<td>$60/10^5$ and ↑</td>
</tr>
<tr>
<td>Demographics</td>
<td>Post&gt;Pre-menopause</td>
<td>Pre&gt;Post menopause</td>
</tr>
<tr>
<td>Receptors status</td>
<td>similar</td>
<td>Similar, ↑ HER-2/neu</td>
</tr>
<tr>
<td>(Estrogen, progesterone, p53, HER-2/neu))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prognosis</td>
<td>73% 5 year survival</td>
<td>• 58-84% 5 year survival depending on resources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• later stage dx → ↓ survival</td>
</tr>
</tbody>
</table>

Tamoxifen in Breast Cancer

Tamoxifen indicated for estrogen (+) breast cancer to prevent recurrence after surgery

Active Metabolites

- Extensive metabolizers
  - ↑ Plasma level
  - ↑ Relapse free survival

Poor metabolizers
  - ↓ Plasma level
  - ↓ Relapse free survival

EM- extensive metabolizers
IM- intermediate metabolizers
PM- poor metabolizers

- 15-21% Caucasian
- ~ 57% Asian
- 20-34% African-American American

### Diet, Exercise & Lifestyle

Compared Japanese-Americans to Native Japanese

30 year longitudinal study of healthy & type 2 diabetics — currently or originally from Hiroshima

<table>
<thead>
<tr>
<th></th>
<th>Japanese-Americans</th>
<th>Japanese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet &amp; exercise</td>
<td>• ↓ complex carbs</td>
<td>• ↑ complex carbs</td>
</tr>
<tr>
<td></td>
<td>• ↑ animal fat</td>
<td>• ↓ animal fat</td>
</tr>
<tr>
<td></td>
<td>• ↓ exercise</td>
<td>• ↑ exercise</td>
</tr>
<tr>
<td>Diabetes Diagnosis @ 40 yrs (1978-88)</td>
<td>18.9% Hawaii (n=873)</td>
<td>6.2% (n=2510)</td>
</tr>
<tr>
<td></td>
<td>13.7% LA (n=1175)</td>
<td></td>
</tr>
<tr>
<td>Biochemistry (serum)</td>
<td>• Cholesterol 2x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Triglycerides 1.5 x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• ↑ glucose fasting</td>
<td></td>
</tr>
<tr>
<td>Ischemic heart disease mortality</td>
<td>44% (n= 2551)</td>
<td>12.3% (n=9737)</td>
</tr>
</tbody>
</table>

Biomedicine & Pharmacol 58: 571, 2004
## Evidence for Differences

### Type 2 Diabetes

<table>
<thead>
<tr>
<th></th>
<th>Asian relative to Caucasian</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td>• Younger</td>
</tr>
<tr>
<td></td>
<td>• Prevalence less but rapidly increasing</td>
</tr>
<tr>
<td><strong>Body</strong></td>
<td>• Normal to &lt;overweight using BMI</td>
</tr>
<tr>
<td></td>
<td>• Diabetes risk increased at lower BMI</td>
</tr>
<tr>
<td></td>
<td>• More visceral fat than Europeans at same BMI</td>
</tr>
<tr>
<td><strong>Complications</strong></td>
<td>End stage renal disease &amp; stroke more common</td>
</tr>
<tr>
<td><strong>Genetics</strong></td>
<td>No clear difference</td>
</tr>
<tr>
<td><strong>Drug response</strong></td>
<td>No known differences</td>
</tr>
</tbody>
</table>

JAMA 301:2129, 2009
Disease Summary

• Significant disease differences exist
• All differences need to be placed in clinical significance context
• Many diseases have either not been as thoroughly investigated in Asians relative to U.S. and Europe
• Asian government-academic opportunities
Pharmacokinetics

Ethnic differences

- **Absorption**
  - Passive: no differences
  - Active (transporters): potential

- **Metabolism**
  - Phase 1: >300 alleles various enzymes. Ethnic differences. Some clinically significant
  - Phase 2: >13 alleles different enzymes. Differences.

- **Distribution & excretion**
  - Passive: no difference
  - Active (transporters): potential

- **Human Pharmacokinetics**
  - Differences reflecting active processes
  - Small N~12 in studies
  - No guidance on patient selection, number, design
  - Not in drug development decision pathway. Not predictive of dosing
Dilemma

• Current bridging path is too simplistic to guide drug use and dosing in bridged population

• Potential variables influencing efficacy and safety are too many and complex to effectively and efficiently create development plan and trial designs

• Regulators worry about disease differences, but little guidance available

• So, what to do?
Development-Regulatory Scenarios

1. Sequential: approve elsewhere, local bridge

   Dose-Response -> Phase 3 Confirm -> Reviews
   
   U.S.-EU -> U.S.-EU
   
   FDA, EMEA
   
   Bridging
   
   China, Japan
   
   Reviews
   
   SFDA, PMDA

2. Parallel: Global development plan & Phase 3 trial(s), simultaneous approvals

   Dose-Response -> Phase 3 Confirm -> Reviews
   
   U.S.-EU -> U.S.-EU
   
   Asia
   
   FDA, EMEA, SFDA, PMDA

3. Modeling & Simulation (M&S)-confirmation based

   Dose-Response -> Phase 3 Confirm -> Reviews
   
   U.S.-EU
   
   M&S, Confirm
   
   China, Japan
   
   FDA, EMEA
   
   SFDA, PMDA
   
   Phase 4
   
   Safety:Efficacy, Re-label
   
   China, Japan
# Scenario Comparisons

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time to market</strong></td>
<td>4-5 years longer than 2.</td>
<td>fastest</td>
<td>0.5-1 year longer* than 2.</td>
</tr>
<tr>
<td><strong>Expense</strong></td>
<td>$$</td>
<td>$$$$$$</td>
<td>$$*$</td>
</tr>
<tr>
<td><strong>Dose-Response</strong></td>
<td>Poor</td>
<td>Good</td>
<td>Best</td>
</tr>
<tr>
<td><strong>Efficacy</strong></td>
<td>Poor</td>
<td>Good</td>
<td>Best</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Poor</td>
<td>Good</td>
<td>Best</td>
</tr>
<tr>
<td><strong>Regulatory Change?</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Could be less time and expense
Example
Are Asians Better (↑) or Worse (↓) than Average Drug Response in NSCLC?

Better than average response

Modeling & Simulation

• **Model**
  – **Disease** mechanistic or empirical relationships to primary disease endpoints
  – **Pharmacology**: known prior dose-response (PK-PD) relationships to biomarkers, intermediate or primary endpoints (Phase 1, 2)
  – **Asian** phenotypes & genotypes (disease, adme, PD)
  – **Prior knowledge** (publications, NDA reviews) with disease & drug class
    • Baseline
    • Dropout

• **Simulate**
  – Asian clinical trial design(s) for Phase 2, 3, 4
Non-Small Cell Lung Cancer Model
(Yaning Wang et al)

- 4 NSCLC registration trial data used to develop model linking survival to risk factors and tumor size change during treatment
- Reason: To facilitate drug development decisions regarding trial design and treatment effect (high trial failure rate)
- Registration trials: bevacizumab, docetaxel, erlotinib, pemetrexed
- Number of patients: 3,398 total; 2,445 with baseline & week 8 post-Rx start
- The full model

\[ \log(T) = \alpha_0 + \alpha_1 \times ECOG + \alpha_2 \times (Baseline - 8.5) + \alpha_3 \times PTR_{wk8} + \varepsilon_{TD} \]

- \( T \) = time to death (days)
- \( \alpha_0 \) = intercept
- \( \alpha_1, \alpha_2, \alpha_3 \) = slopes for ECOG
- ECOG = Eastern Cooperative Oncology Group performance score
- \( PTR_{wk8} \) = % tumor reduction from baseline
- \( \varepsilon_{TD} \) = residual variability

NSCLC Patient Survival Curves Predicted vs Observed
(Solid & broken black lines: survival curve & 95% CI: Gray line & shaded area: predicted)
Model Based Non-small Cell Lung Cancer Development in Asia

Disease Model (NSCLC)

Drug Model Library
- Erlotinib
- Gefitinib
- Docetaxel
- Platins
- Combinations

Virtual Populations
- Phenotypes & Genotypes
  - Chinese
  - American
  - European

Simulation Opportunities
- Trial design
- Efficacy-Safety
- Personalized medicine
  - Dosing
  - Combo’s
  - Biomarkers
  - Target selection

Learning
- Completed Trials
- Post-market surveillance
- Mechanistic research

Situation Models (clinical trials, market population)

Economic Models
Steps to Regional Drug Development Quality

**Pharma Industry**
1. Determine if ICH5 (possibly others) needs revision to account for regional disease differences
2. Create global disease assessment accounting for ethnic & regional differences if any
3. Create global development plan accounting for significant disease, PK-ADME, & PD differences by region
4. Recommend regional development path based on clinical, regulatory & commercial character

**Regional Regulatory Agencies**
1. Determine if ICH5 (possibly others) needs revision to account for regional disease differences
2. Decide local experience required & principles for
   - When to engage company on development strategy
   - Willingness to accept simulation to justify plans
   - Dose-response strategy
   - Confirmatory Phase 3 strategy
   - Willingness to use Phase 4 commitment to gain efficiency
3. Decide if collaboration between regional countries will be synergistic?
Recommendations

• **Disease ethnic difference research** (pathogenesis, epidemiology, treatment). Governments
• **Need public meetings** on global development strategy & regulatory congruence
• **In silico demonstration project**. Pick a disease & therapeutic target. Develop disease-drug models & virtual patient-ethnic population. Government, Industry, Academia
• **Change regulatory policy** in stepwise manner.
• **International transparency** on regulatory decisions to promote synchronization
• **Change drug development practice** starting at Phase 0
• **Regional regulatory collaboration** could balance local needs & development efficiency
Backups
Global Clinical Trials (GCT) in Japan 2007-2009

(a) Numbers of CTNs

(b) Numbers of GCTs

- Clinical trial notification (CTN) submitted for approval
- Global Clinical Trial (GCT) number
- GCT %
Scenario Planning for Development
(front-loading knowledge & planning)

• Pre-IND
  – Critical disease review relative to dose-response, efficacy & safety linked to Phase 1-3 development plan
  – Customize international plan according to ethnic and country-regional differences in disease, demographics, values & practices
    • No disease difference. Verify & confirm with regulators early
    • Differences in disease &/or demographics, then simulate & confirm
Scenario Planning for Development  
(front-loading knowledge & planning)

• Phase 1
  – Conduct single dose-multiple dose PK-PD
  – No ethnic study until full scale development decision
  – Design phase 2 a&b trials with disease modeling & trial simulation

• Phase 2
  – 2a. PK-PD driven if possible
    • End of phase 2a meeting with regulators. Simulate 2b-3 designs
  – 2b. Adaptive design if possible. Seamless to 3?
  – Ethnicity. Conduct PK-PD driven comparative study to set dosing in Global Phase 3 trial. Patients from target countries (Asians from Asia)
  – Simulate Phase 3 global design
Scenario Planning for Development  
(front-loading knowledge & planning)

• Phase 3 trial recommendation
  • One trial designed to optimize finding efficacy & minimize uncertainty (e.g., enrichment, fewer sites)
  • One global trial designed to find efficacy & safety in global population

• Phase 4 (view as continuum from 1-3 r&d driven)
  – Confirm safety in passive + structured surveillance studies
  – Confirm efficacy in local patients with varying disease severity, age and other factors that makes sense
A New International Drug Development Strategy

1. Is the disease likely to be different in the to be bridged population?
   a) Government-academia.
      I. Conduct pathogenesis & disease progression studies including contemporary genotype-phenotype techniques
      II. Develop and maintain key disease models
      III. Develop virtual patient population based on this information
   b) Company. Prepare comparative ethnic disease review pre-IND. Include likely significant differences in Phase 2-3 & 4 global plan. Power studies and employ inclusion-exclusion criteria based on this information

2. Is dose-response the same relative to efficacy and safety from one country or ethnic group to another? Company will
   a) Simulate studies based on preclinical drug-biomarker relationship for
      I. Single dose or short-term PK-PD trial in bridged and primary population sample
      II. Phase 2a & b trial designs
   b) Use results of each in subsequent trials

3. Are efficacy and safety the same in Phase 3 trial populations? Company will
   1. Simulate Phase 3 trial designs during phase 1-2 based on disease model, drug model and clinical trial data models and desired product profile
   2. Discuss simulations with regulators at End of Phase 2a type meeting. Agree design.
   3. Conduct two different phase 3 trials or one trial with subsets based on simulation results

4. Post-market continue development for additional patient subgroups (e.g., disease severity) and potential safety signals again based on simulation driven decisions
Tamoxifen in Breast Cancer

**Chemical Reaction Diagram:**
- **Tamoxifen (TAM)**
- **CYP2D6** (CYP2D6, CYP2C9, CYP2C19, CYP3A)
- **N-desmethylTAM**
- **CYP3A4/5** (CYP2C9 + other CYP isoforms)
- **4-hydroxyTAM**
- **CYP3A4/5**
- **Endoxifen**

**Survival Curves:**
- **Extensive** (n=115)
- **Decreased** (n=65)

**Years after randomization:**
- **Relapse-free survival (%)**

**Statistical Significance:**
- **P=0.007**
- **P=0.009**
The Need

- **Efficacy**
  - Quantitatively describe efficacy in terms of patient benefits relative to patient characteristics and dose
  - Individuals. Know who is most likely to respond
- **Safety**
  - Identify and quantitatively describe common and rare risks related to patient characteristics and dose.
  - Individuals. Know who is likely to be at risk and how to decrease it
- **Dosing regimen**
  - Justify based on a thorough understanding of benefit and risk for patient populations and individuals
- **Labeling**
  - Capture the above information in a manner that helps clinicians and patients make optimal therapeutic decisions
- **Cost**
  - Avoid unnecessary duplication in drug development due to high expense
- **Time**
  - Useful drugs should be available as quickly as possible for patients in need
Bridging Definition

• Definitions (ICH5):
  – Bridging Study. ‘is defined as a supplemental study performed in the new region to provide pharmacodynamic or clinical data on efficacy, safety, dosage and dose regimen in the new region that will allow extrapolation of the foreign clinical data to the new region. Such studies could include additional pharmacokinetic information.’
  – Bridging Data Package. ‘Selected information from the Complete Clinical Data Package that is relevant to the population of the new region, including pharmacokinetic data, and any preliminary pharmacodynamic and dose-response data and, if needed, supplemental data obtained from a bridging study in the new region that will allow extrapolation of the foreign safety and efficacy data to the population of the new region.’
## Drug Metabolism

**Enzymes & Mutant alleles (large N)**

**Significant Ethnic Differences**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Allele Number</th>
<th>Asian relative to Caucasian</th>
<th>Drug example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CYP1A1</td>
<td>&gt;15</td>
<td>?</td>
<td>R-warfarin</td>
</tr>
<tr>
<td>CYP2B6</td>
<td>11</td>
<td>?</td>
<td>Buproprion</td>
</tr>
<tr>
<td>CYP2C8</td>
<td>20</td>
<td>Differences</td>
<td>Paclitaxel</td>
</tr>
<tr>
<td>CYP2C9</td>
<td>38</td>
<td>↑ PM</td>
<td>Warfarin, rosuvastatin</td>
</tr>
<tr>
<td>CYP2C19</td>
<td>8</td>
<td>↑ PM</td>
<td>Mephenytoin, diazepam</td>
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<tr>
<td>CYP2D6</td>
<td>75</td>
<td>↑ PM</td>
<td>Codeine, tamoxifen</td>
</tr>
<tr>
<td>CYP3A4</td>
<td>≥40</td>
<td>?</td>
<td>Irinotecan, gefitinib</td>
</tr>
<tr>
<td>CYP3A5</td>
<td>26</td>
<td>?</td>
<td>Nifedipine, tacrolimus</td>
</tr>
<tr>
<td>DPD</td>
<td>39</td>
<td>Differences</td>
<td>5-fluorouracil</td>
</tr>
<tr>
<td>TPMT</td>
<td>29</td>
<td>Small differences</td>
<td>6-mercaptopurine</td>
</tr>
<tr>
<td><strong>Phase 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GST</td>
<td>13</td>
<td>Differences</td>
<td>Adriamycin, BCNU</td>
</tr>
<tr>
<td>UGT (5 subtypes)</td>
<td>multiple alleles</td>
<td>Differences</td>
<td>Irinotecan, morphine</td>
</tr>
</tbody>
</table>

**Importance depends on fractional clearance & therapeutic index**

*Expert Opin Drug Metab Toxicol 5: 243, 2009*
Transporters in Drug Absorption and Distribution

- 19 Known & growing
- Genetically controlled and ethnic differences

a) Intestinal epithelia

b) Hepatocytes

c) Kidney proximal tubules

d) Blood–brain barrier

# Selected Transporter Drug-Drug Interactions

<table>
<thead>
<tr>
<th>Implicated transporter*</th>
<th>Interacting drug</th>
<th>Affected drug</th>
<th>Clinical pharmacokinetic impact on affected drug‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic anion transporting polypeptides</td>
<td>Cyclosporine</td>
<td>Pravastatin</td>
<td>$\text{AUC} \uparrow 890%$ and $C_{\text{max}} \uparrow 678%^{101,204}$</td>
</tr>
<tr>
<td></td>
<td>Cyclosporine</td>
<td>Rosuvastatin</td>
<td>$\text{AUC} \uparrow 610%^{205}$</td>
</tr>
<tr>
<td></td>
<td>Cyclosporine</td>
<td>Pitavastatin</td>
<td>$\text{AUC} \uparrow 360%$ and $C_{\text{max}} \uparrow 560%^{206}$</td>
</tr>
<tr>
<td></td>
<td>Rifampicin (single dose)</td>
<td>Glyburide</td>
<td>$\text{AUC} \uparrow 125%^{207}$</td>
</tr>
<tr>
<td></td>
<td>Rifampicin (single dose)</td>
<td>Bosentan</td>
<td>$C_{\text{trough}} \uparrow 500%^{208}$</td>
</tr>
<tr>
<td></td>
<td>Lopinavir/ritonavir</td>
<td>Bosentan</td>
<td>Day 4: $C_{\text{trough}} \uparrow 4,700%^{208}$; day 10: $C_{\text{trough}} \uparrow 400%^{208}$</td>
</tr>
<tr>
<td></td>
<td>Lopinavir/ritonavir</td>
<td>Rosuvastatin</td>
<td>$\text{AUC} \uparrow 107%$ and $C_{\text{max}} \uparrow 365%^{209}$</td>
</tr>
<tr>
<td>Organic anion transporters</td>
<td>Probenecid</td>
<td>Cidofovir</td>
<td>$\text{CL}_r \downarrow 32%^{210,211}$</td>
</tr>
<tr>
<td></td>
<td>Probenecid</td>
<td>Furosemide</td>
<td>$\text{CL}_r \downarrow 66%^{210}$</td>
</tr>
<tr>
<td></td>
<td>Probenecid</td>
<td>Acyclovir</td>
<td>$\text{CL}_r \downarrow 32%$ and $\text{AUC} \uparrow 40%^{210,212}$</td>
</tr>
<tr>
<td>Organic cation transporters</td>
<td>Cimetidine</td>
<td>Metformin</td>
<td>$\text{AUC} \uparrow 50%$ and $\text{CL}_r \downarrow 27%^{213,214}$</td>
</tr>
<tr>
<td></td>
<td>Cimetidine</td>
<td>Pindolol</td>
<td>$\text{CL}_r \downarrow 34%^{215}$</td>
</tr>
<tr>
<td></td>
<td>Cimetidine</td>
<td>Varenicline</td>
<td>$\text{AUC} \uparrow 29%^{216}$</td>
</tr>
<tr>
<td></td>
<td>Cimetidine</td>
<td>Pilsicainide</td>
<td>$\text{AUC} \uparrow 33%, \text{CL}_r \downarrow 28%^{217}$</td>
</tr>
<tr>
<td></td>
<td>Cetirizine</td>
<td>Pilsicainide</td>
<td>$\text{CL}_r \downarrow 41%^{218}$</td>
</tr>
<tr>
<td></td>
<td>Cimetidine</td>
<td>Dofetilide</td>
<td>$\text{CL}_r \downarrow 33%^{219}$</td>
</tr>
<tr>
<td>P-glycoprotein</td>
<td>Quinidine</td>
<td>Digoxin</td>
<td>$\text{CL}_r \downarrow 34-48%^{220,221}$</td>
</tr>
<tr>
<td></td>
<td>Ritonavir</td>
<td>Digoxin</td>
<td>$\text{AUC} \uparrow 86%^{212}$</td>
</tr>
<tr>
<td></td>
<td>Dronedarone</td>
<td>Digoxin</td>
<td>$\text{AUC} \uparrow 157%$ and $C_{\text{max}} \uparrow 75%^{223}$</td>
</tr>
<tr>
<td></td>
<td>Ranolazine</td>
<td>Digoxin</td>
<td>$\text{AUC} \uparrow 60%$ and $C_{\text{max}} \uparrow 46%^{224}$</td>
</tr>
<tr>
<td>Breast cancer resistance protein</td>
<td>GF120918</td>
<td>Topotecan</td>
<td>$\text{AUC} \uparrow 143%^{225}$</td>
</tr>
</tbody>
</table>
Evidence for Differences
Pharmacokinetics

- Few differences
- Studies often not designed to find a difference in terms of patient selection criteria or number linked to a critical clearance difference relative to therapeutic index (e.g., 25%)
- Studies often not in the decision chain for trial design information (e.g., conducted late)
- A PK difference may not translate to a dosing recommendation, but rather the potential need for dosing data and recommendations
- PD differences (e.g., receptor prevalence, EGFR) may be opportunities for enrichment
Development Phase for Global Clinical Trials in Japan 2007-2009

- Phase I: 2.4%
- Phase II: 26.2%
- Phase III: 71.4%
Ethnicity Global Strategy
Recommendation from Japan

a) Various global development strategies

- PK study in all regions (simultaneously or separately in same protocol)
- Option B
- Option A
- Option D
- Option C
- Final dose in region III is different from other regions
- Final dose is same in all regions
- Global postmarket assessment based on postmarket studies (simultaneously or independently in region C)

b) Possible options in dose-finding and confirmatory stages

(i) Option in a dose-finding stage
- Option A
  - A. Simultaneous global dose-finding study in all regions
- Option B
  - B-1. Simultaneous global dose-finding study in regions I and II
  - B-2. Independent regional dose-finding study in region III
  - Compare

(ii) Option in a confirmatory stage
- Option C
  - C. Simultaneous global confirmatory study in all regions
- Option D
  - D-1. Simultaneous global confirmatory study in regions I and II
  - D-2. Independent confirmatory study in region III
  - Compare

My assumptions

• I don’t know the extent to which diseases are virtually the same or significantly different between Asia and USA:EU
• There may be a literature bias to show differences
• Even when differences exist, are they clinically significant?
• I’m exploring ways to test this and am looking for curious people
1. Global path needs to support 1st development in EU, USA or Asia
2. Encourage early (e.g., preIND) dialogue on bridging strategy and answers to previous questions.
3. International support for bridging. Develop or amend ICH5
4. Encourage simulation based trial planning meetings (e.g., EOP2a meeting)
5. Facilitate early entry into patients to begin bridging