# Techniques for Visualizing Uncertainty and Perceptions of Risk

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## Abstract

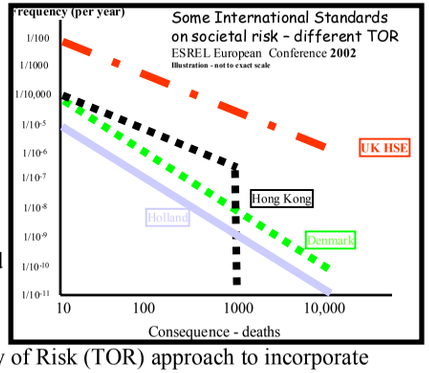
We describe risk imaging software technology developed for Pfizer, Inc. This technology decomposes risk into two elements: (1) the frequency of each kind of harm associated with a hazard and (2) the adversity of each of those harms. In most risk analyses, considerable uncertainty exists regarding the actual magnitude of both the frequency and the adversity of each potential harm. For instance, sampling error, measurement error, and bias all contribute to uncertainty about the frequency. In the case of adversity, differences in opinion, measurement error, and choice of dimensions lead to uncertainty. Because different kinds of harm are measured along often incompatible dimensions, we quantify adversity on a scale obtained by ordination. The method we have developed then bounds estimates of frequency and adversity using quantitative uncertainty techniques. Risk from the hazard is imaged as an area circumscribed by the uncertainty bounds characterizing all of the harms. We refer to this area as a *risk profile* of the hazard. Different individuals and groups respond to uncertainty and risk differently, and the risk profile can be further focused to reflect particular attitudes and visualize particular perceptions of the risk. To do this, we specify values for *attitude parameters*. These attitudes include the overall importance of uncertainty, the meaning of disagreements between measurements or opinions, and the meaning of absence of evidence. Different values specified for these attitude parameters result in different visualizations of risk as perceived by the individual or group. These alternate risk visualizations may be contrasted and compared across management choices or across different risk perceivers to facilitate communication and decision making. To illustrate the methodology, published clinical trial data are imaged.

## Introduction

The Tolerability of Risk (TOR) approach is a commonly used graphical tool for the display of risk.

Risk is graphed on a frequency/consequence scale as a Farmer curve.

Regions of risk are defined as broadly acceptable, tolerable, and intolerable.




We modify the Tolerability of Risk (TOR) approach to incorporate quantitative uncertainty and to use ordinal (ranked) measures of harm.

TOR is useful because it is graphical, simple to generate and explain, and based on normative science.

## Pfizer applied risk research

Pfizer applied risk research is a program that includes risk perception researchers, risk communication researchers, epidemiologists, clinicians, and philosophers of risk.

Our applied risk imaging focuses on health risks. This poster images data regarding safe and common hypertension drugs. The data is publicly available and the analyses are intended to illustrate the risk imaging method only and should not be construed as a risk analysis.

## The RAMAS® Risk Imaging method

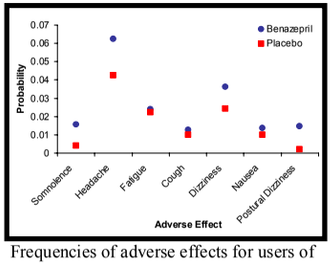
To image risk we (1) Separate adversity data from frequency data, (2) Rank adversity on an ordinal axis, (3) Incorporate uncertainty, (4) Combine uncertain numbers into a risk profile, and (5) Use attitude variables to explore risk perception. Adversity ranking is accomplished using Expert opinion, judgment, or other scores. Uncertainty includes uncertain Frequency, adversity, and dependency.

## Incorporating uncertainty in clinical trial data

### Benazepril data

| Adverse Reaction | Frequency Data: Benazepril (*N*=964) *n* | % | Placebo (*N*=496) *n* | % |
|---|---|---|---|---|
| Headache | 60 | 6.22% | 21 | 4.23% |
| Dizziness | 35 | 3.63% | 12 | 2.42% |
| Fatigue | 23 | 2.39% | 11 | 2.22% |
| Somnolence | 15 | 1.56% | 2 | 0.40% |
| Postural Dizziness | 14 | 1.45% | 1 | 0.20% |
| Nausea | 13 | 1.35% | 5 | 1.01% |
| Cough | 12 | 1.24% | 5 | 1.01% |

Frequencies of adverse effects for benazepril. The data are from the package insert that is reprinted in the *PDR* (1993).



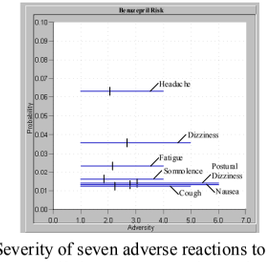

Frequencies of adverse effects for users of the hypertension drug benazepril. The data are from the package insert that is reprinted in the *PDR* (1993).

### Rank adversity

| Adverse Reaction | Adversity Data: *N* | min | mean | max |
|---|---|---|---|---|
| Headache | 14 | 1 | 2.04 | 4 |
| Dizziness | 14 | 1 | 2.71 | 5 |
| Fatigue | 14 | 1 | 2.14 | 4 |
| Somnolence | 14 | 1 | 1.86 | 4 |
| Postural Dizziness | 14 | 1 | 3.07 | 6 |
| Nausea | 14 | 1 | 2.86 | 6 |
| Cough | 14 | 1 | 2.21 | 5 |

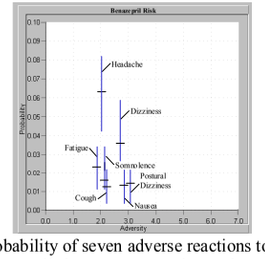
Benazepril adverse effects severity as rated by respondents to an *ad hoc* survey. Effects were scored on a scale of 1 (least severe) to 7 (most severe). *N* is the number of survey respondents, min is the minimum adversity reported, max is the maximum adversity reported, and mean is the average adversity score across all respondents.

### An image of uncertain adversity



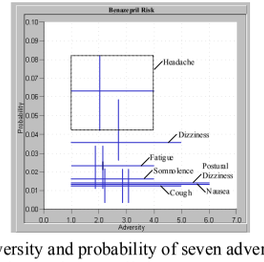

Severity of seven adverse reactions to benazepril shown as uncertain numbers by observed probability. Vertical black lines indicate mean adversity rating for each adverse effect. Note that the vertical axis is truncated at 0.1 for the purpose of display.

### An image of uncertain frequency




Probability of seven adverse reactions to benazepril shown as uncertain numbers (99% confidence intervals) by average adversity rating. Horizontal black lines indicate observed probability for each adverse effect. Note that the vertical axis is truncated at 0.1 for the purpose of display.

### Uncertain frequency and adversity



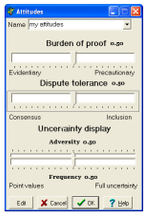

Adversity and probability of seven adverse reactions to benazepril shown as uncertain numbers. The dashed black lines forming a box show bounds around probability and adversity combinations for headache that are consistent with the uncertain data. Note that the vertical axis is truncated at 0.1 for the purpose of display.

## Dependence

Because harms may covary, the frequency of adverse effects at each ordinal level is additionally uncertain. We use bounds based on the Fréchet inequalities that allow for any and all dependencies. Alternately, we could specify dependencies when known, e.g. correlations.

## Quantifying attitudes

Attitude quantification sliders specify a particular risk perceiver's attitudes towards uncertainty.

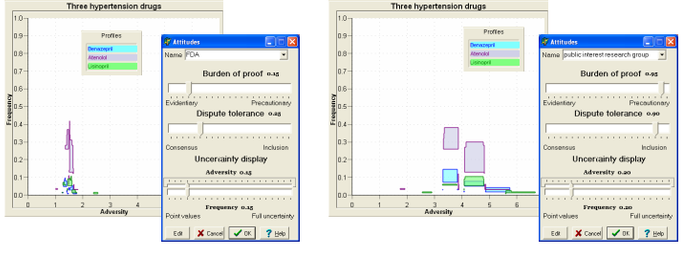



Burden of proof quantifies the perceiver's attitude towards the meaning of absence of evidence.

The Dispute tolerance slider probes the risk perceiver's interpretation of differences in opinion and judgment, differences in models, and differences in information regarding the severity of an adverse event.

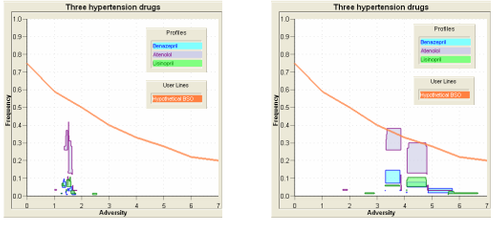
The Uncertainty display slider gauges the risk perceiver's attitudes towards the importance of uncertainty in a risk assessment.

## Comparing risk perceptions




Adjusting the sliders accounts for attitudes towards risk and uncertainty and results in contrasting visualizations of risk perception. The attitude settings for FDA and PIRG are hypothetical. Note that both risk perceptions are consistent with the data.

## Tolerability of risk




The Basic Safety Objective (BSO) line divides acceptable risk from tolerable risk. A hypothetical BSO is shown here. Perceptions of risk tolerability differ between the FDA and the PIRG for one drug, but are similar for the other two drugs.

## Summary

Incorporating uncertainty regarding frequency, adversity, and dependence bounds risk. All risk perceptions within the bounded area are consistent with the data and the stated uncertainty.

Risk perception varies across individuals and interest groups. Attitude parameters can characterize this variability.

If uncertainty and attitudes can be quantified, risk imaging may help clarify contrasting risk perceptions and aid risk communication.