Toxicology 101

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Overview

- What is forensic toxicology?
- Sub-disciplines
- Role of the toxicologist
- Laboratory methodology
- Interpretation
- Challenges
Toothbrush Defense
Drugs and Poisons in Biological Samples

Three sub-disciplines:

- Human performance toxicology
- Postmortem forensic toxicology
- Forensic urine drug testing
Forensic Toxicology

Drugs and Poisons in Biological Samples

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Drugs and Poisons in Biological Samples

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What is Human Performance Toxicology?

- “Behavioral toxicology”
- How drugs influence human performance or behavior
  - Improve performance (e.g. athletics)
  - Decrease performance (e.g. criminal context)
    - Impaired driving
    - Drug-facilitated sexual assault
    - Other criminal acts while under the influence of a drug
    - (Death investigation)
Role of the Toxicologist

- Test
- Interpret
- Testify

- B.S. Chemistry, biology or related science
- M.S. or Ph.D. in Chemistry, FS or related science
Toxicology Testing

Alcohol
- Gas chromatography-Flame Ionization Detection (GC-FID)
- Headspace GC
- Standardized methodology
- Well established and accepted

Drugs
- Two-step process
  - Screening (often “immunoassay”)
  - Confirmation e.g. GC-MS
- Many procedures (many drugs)
- Well established and accepted
Drug Testing – Step 1
Presumptive Screen

- Antibody-based test (immunoassay)
- Defined “cutoffs”
- Know what these are
- Know what drugs are included in the screen
- Limited scope
- Used to determine what additional tests are necessary
- Rapid (hours)
- False positives & negatives possible
- Not forensically defensible without confirmation
Cutoff Concentration

POSITIVE

e.g. 100 ng/mL
Cutoff Concentration

POSITIVE

e.g. 100 ng/mL

NEGATIVE
Drug Testing – Part II Confirmation

- Gas chromatography-mass spectrometry (GC-MS) or similar
- Sensitive and specific
- Separate and identify
- Used for qualitative and quantitative testing
- Forensically defensible
- Typically report drugs if they are detectable and/or meet specific criteria – rather than an administrative cutoff
- Broad scope (hundreds of drugs)
- Requires separation of the drug from the matrix (blood)
- Labor intensive
- Expensive
Analytical Issues

- Methodology widely accepted
- Extensive scientific literature
- Results may vary between laboratories
  - Sample storage/degradation (biological matrix)
  - Scope of testing
  - Cutoffs vary between labs
  - Equipment/resources in the laboratory
  - Limits of detection/analytical capabilities
  - Policies/procedures regarding testing protocols
  - Non reportable data
Why does it take so long?

- Complex biological matrices
- Isolate the substances prior to analysis
- Purification process (extraction) is labor intensive
- Specific procedures for isolation each drug or class of drug
- Specific procedures for analysis each drug or class of drug
- Results subject to technical/administrative review
Impaired Driving

Alcohol
- Notably the most prevalent drug in impaired driving
- Effects, properties and pharmacokinetics are well understood
- Produce predictable effects in a dose-dependent manner
- Per-se approach

Drugs
- Prevalence not well understood (likely underestimated)
- Many drugs involved (hundreds)
- Scientific literature less mature
- Effects are less predictable
- May require proof of impairment
What level of [DRUG] is equivalent to a .08 BAC?

*Any* level of [DRUG] indicates impairment.

Quantitative vs. Qualitative toxicology reports *(Do you need a NUMBER?)*

Can we interpret based upon lab report alone?

Polypharmacy issues – multiple drug/alcohol combinations

Training needs

- New methods for new drugs
- Interpretive testimony

Why is the report NEGATIVE?
Are Drugs Important?

- **10 million** people reported driving after illicit drug use (SAMHSA, 2007)
- Drugs (other than alcohol) found in 17.8% fatally injured drivers (NHTSA)
- Drugs detected in 10 to 22% of drivers involved in crashes, often in combination with alcohol
- Drugs detected in up to 40% of injured drivers requiring medical treatment
- Drug use among drivers arrested for motor vehicle offenses is 15-50%
- Driving under the influence of drugs (DUID) is highly significant

SAMHSA – Substance Abuse and Mental Health Services Administration
NHTSA – National Highway Traffic Safety Administration
Impaired Driving Constants

- DUID inherently more complex (scientifically and legally) than alcohol-related DWI
- Fewer studies than for alcohol
- Requires toxicologists with specialized training to interpret effects
- Drug *impairment* is determined on a case-by-case basis
- DUID represents a significant number of DWIs
- More difficult to prosecute than alcohol-impaired driving
- Under-reported, under-recognized
- Drugs are constant factor in traffic crashes
- Full impact – not yet known
Impaired Driving Variables

- Statutory schemes vary state to state:
- May require the drug to render a driver *incapable of driving safely*
- May require the drug to *impair a driver’s ability to operate a vehicle safely* or require a driver to be “under the influence”, “impaired” or otherwise affected by an *intoxicating drug*
- “Per-se” or “zero tolerance” drug laws which make it a criminal offense to have a specified drug or metabolite in the body while operating a motor vehicle
- Laboratory policies and procedures vary
- Particularly SOPs, quantitative vs. qualitative services, analytic capability/instrumentation, resources, training
- All these SCIENTIFIC and LEGAL **variables** may influence how we **interpret** a case
Drugs Used
Drugs most commonly associated with impaired driving:

- **Cannabinoids/Marijuana**
- **CNS Depressants**
  Sedative-hypnotics, muscle relaxants, antidepressants, antihistamines, anticonvulsants, antipsychotics, anxiolytics
- **CNS Stimulants**
  Cocaine, methamphetamine
- **Narcotic Analgesics**
  Morphine, codeine, hydrocodone (Vicodin), oxycodone (Oxycontin), methadone
Top Ten List

1. THC & metabolite (Carboxy-THC)
2. Cocaine and metabolite (Benzoylecgonine)
3. Methamphetamine
4. Diazepam and metabolite (Nordiazepam)
5. Carisoprodol and metabolite (Meprobamate)
6. Hydrocodone
7. Morphine
8. Alprazolam
9. Zolpidem
10. Methadone
1. Any drug that can affect the brain’s perception, collection, processing, storage or critical evaluation processes

2. Any drug that affects communication of the brain’s commands to muscles or organ systems that execute them

For the most part, drugs that affect the central nervous system (CNS)
Drug Toxicology Challenges

- More complex
- Often in combination with other drugs and/or alcohol (additive or synergistic effects)
- Scientific literature is complex
- May require a toxicologist to interpret the results and provide an opinion
- These complex issues must be explained to the court using every day language
Impairment is based on knowledge of the drug(s), intended effects, side effects and toxic effects

The toxicologist can rarely give an opinion based upon the drug report alone

The opinion may depend on the context of the case and information gathered by the investigator (situation, environment, observations, performance on field sobriety tests, other evaluations, driving pattern etc.)
Positive Tox

Poor Driving

Signs and Symptoms
Drug Interpretation Issues

- Multiple drug use
- Tolerance (chronic vs. naïve)
- Health
- Metabolism
- Individual sensitivity/response
- Withdrawal
- Put in context of case e.g. environmental factors
- Other factors (distraction, injuries, disease etc)
Signs and Symptoms: Depressants

- Confusion
- Poor divided attention
- Sedation
- Droopy eyelids
- Slowed reaction times
- Memory effects
- HGN

- Poor balance
- Poor coordination
- Unsteadiness
- Slurred speech
- Disorientation
- Low b.p.
- Low pulse
“Once more, only this time touch your nose.”
Drug Evaluation and Classification

- Systematic, standardized, post-arrest procedure for Drug Evaluation and Classification (DEC)
- Performed by a trained and certified police officer
- Formally and scientifically validated for drugs
- DEC Certified officers are Drug Recognition Experts (DREs)
- 12-step evaluation of behavior, appearance, psychophysical tests, vital signs, eye measurements
- DRE documents drug signs and symptoms – provides opinion as to which class of drug is responsible for impairment. These can be interpreted by a Toxicologist in a DUID case
- **DRE provides the court with additional information**
Driving Behavior
- Depressants -

- Weaving
- Extreme lane of travel
- Striking other vehicles
- Striking fixed objects
- Slow speed
- Hit and run
- Wrong way driving
Interpretation Requires Information From Many Sources:
What does the number actually mean???
## Toxicology Blood Ranges

<table>
<thead>
<tr>
<th>Drug</th>
<th>Concentration Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboxy-THC THC</td>
<td>6 – 282 ng/mL</td>
</tr>
<tr>
<td>THC</td>
<td>2 – 23 ng/mL</td>
</tr>
<tr>
<td>BE Cocaine</td>
<td>0.01 – 10 mg/L</td>
</tr>
<tr>
<td></td>
<td>0.005 – 0.64 mg/L</td>
</tr>
<tr>
<td>Methamphetamine</td>
<td>0.05 – 14 mg/L</td>
</tr>
<tr>
<td>Amphetamine</td>
<td>0.01 – 0.19 mg/L</td>
</tr>
<tr>
<td>Diazepam</td>
<td>0.03 – 5 mg/L</td>
</tr>
<tr>
<td>Nordiazepam</td>
<td>0.03 – 3.2 mg/L</td>
</tr>
</tbody>
</table>

**Definition of Statistics:** *The science of producing unreliable facts from reliable figures*
Example: Methamphetamine High vs Low

Concentration

Effects

- Fatigue
- Exhaustion
- Confusion
- Hypersomnolence
- Depression

Excitation
- Exhilaration
- Feel “good”

Hyperactive
- Agitated
- Paranoia
- Confusion
- Delusional
- Irrational
- Violent

Concentration
Use of Quantitative Results

- Provides valuable information from an interpretive standpoint
- Must be used responsibly
- Should not be interpreted in isolation
- Toxicologist should be prepared to discuss interpretive limitations
The Scientific Literature

- Empirical Considerations
- Epidemiological Studies
- Case Reports
- Laboratory Studies
- Simulator Studies
- On-the-road driving studies
Limitations

- Often not real-world doses
- Often not real driving
- Less complex tasks
- Small populations
- Drug combinations
Male, 48y

- Vehicle swerves into oncoming traffic
- Speech slurred, watery eyes, HGN present
- Unsteady on his feet, staggering
- Falls over during OLS, WAT
- Stated that he swerved “To pick up a tamale”
- BAC 0.00%

Toxicology:
- Morphine 0.05 mg/L
- Meprobamate 20 mg/L
- Carisoprodol 2 mg/L
- Oxycodone 0.13 mg/L
- Hydrocodone 0.06 mg/L
- Diazepam 0.3 mg/L
- Nordiazepam 0.3 mg/L
- Gabapentin, present.
Recommendations for Toxicological Investigation of Drug Impaired Driving

ABSTRACT: Investigations of suspected drivers in drug-impaired driving (DID) cases usually require several key elements, including a trained team of investigators with expertise in chemical and physics investigations, a toxicological opinion for the comprehensive toxicological analysis, and an analytical report with supporting evidence. The current methods for detecting and quantifying drugs in blood and urine are generally accepted as reliable and accurate for the purpose of determining the presence or absence of drugs in the body. In the United States, the most common drugs detected are marijuana, cocaine, opioids, and benzodiazepines. The most frequently implicated drugs are marijuana and cocaine, followed by opioids and benzodiazepines. These substances are known to impair driving ability, leading to increased risk of accidents and fatalities. The use of these drugs in combination with alcohol can further exacerbate the effects, resulting in even more significant impairment.

KEYWORDS: Motor vehicle accidents, drug-impaired driving, impaired performance, automobile driving, driving under the influence of drugs

Toxicologically, the United States has been focusing on the need for more standardization in the scope and analytical cutoffs used in drug testing performed in drug-impaired driving investigations. In 2004, the Virginia Department of Motor Vehicles (DMV) identified several key elements, including a team of investigators with expertise in chemical and physics investigations, a toxicological opinion for comprehensive toxicological analysis, and an analytical report with supporting evidence. The current methods for detecting and quantifying drugs in blood and urine are generally accepted as reliable and accurate for the purpose of determining the presence or absence of drugs in the body. In the United States, the most common drugs detected are marijuana, cocaine, opioids, and benzodiazepines. The most frequently implicated drugs are marijuana and cocaine, followed by opioids and benzodiazepines. These substances are known to impair driving ability, leading to increased risk of accidents and fatalities. The use of these drugs in combination with alcohol can further exacerbate the effects, resulting in even more significant impairment.

Survey of Current Practice

Current practices in toxicological laboratories supporting DIDE programs were compared to a survey of all participating labs that could be identified. The survey included questions on scope and analytical cutoffs of services provided, as well as statistics on the frequency of drugs detected in DIDE cases. The survey was conducted in 2004-2005 and represents a variety of state and federal agencies involved in DIDE investigations. The survey results showed significant variation between laboratories in terms of scope and analytical cutoffs used in testing performed in DIDE cases. One-hundred percent of survey respondents used immunologic screening to perform presumptive drug screening on blood and urine specimens. Forty-one percent of the responding laboratories added...
Additional Resources

- Drug Toxicology for Prosecutors
  American Prosecutors Research Institute, 2004.

- Drugs and Human Performance Fact Sheets, DOT HS 809 725, National Highway and Traffic Safety Administration, 2004
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