Drugs and Alcohol: Toxicology

Introduction

- Toxicologists are charged with the responsibility for detecting and identifying the presence of drugs and poisons in body fluids, tissues, and organs.
- Toxicologists not only work in crime laboratories and medical examiners' offices, but may also reach into hospital laboratories and health facilities to identify a drug overdose or monitor the intake of drugs.
- A major branch of forensic toxicology deals with the measurement of alcohol in the body for matters that pertain to violations of criminal law.

What is Toxicology?

- Toxicological examinations involve the identification and often quantization of drugs & toxic materials in the human body
- The role of the forensic toxicologist is limited to matters pertaining to violations of criminal law
  - determination of the presence of alcohol in the body
  - identification of substances causing unnatural death

Properties of Alcohol

- Alcohol is a general term for a family of organic compounds
  - commonly encountered members include methanol, ethanol, isopropanol
- The term alcohol will be taken to mean ethanol (ethyl alcohol, CH₃CH₂OH)

Chemical Properties of Ethanol

- A clear volatile liquid
- Burns easily
  - oxidizes easily
- Slight, characteristic odor
- Is very soluble in water
  - miscible in all proportions

Physiological Properties of Ethanol

- A central nervous system (CNS) depressant
- CNS is the bodily system which is most severely affected by alcohol
- The degree to which the CNS function is impaired is directly proportional to the concentration of alcohol in the blood
What Does the Body Do With Alcohol?

- When an alcoholic beverage is swallowed, it is diluted by stomach juices & quickly distributed throughout the body
- Alcohol does not require digestion before its absorption into the bloodstream
  - some diffuses into bloodstream directly through the stomach wall
  - remainder passes into the small intestine rapidly absorbed & circulated

Alcohol Absorption

- Alcohol is absorbed from all parts of the gastrointestinal tract largely by simple diffusion into the blood
  - small intestine is the most efficient region for absorption because of its large surface area
- The rate of absorption varies according to the particular beverage & the state of the consumer's stomach

Alcohol Absorption

- Fasting individual
  - 20-25% of a dose of alcohol is absorbed from the stomach
  - 75-80% is absorbed from the small intestine
  - peak blood alcohol concentrations occur in 0.5-2.0 hrs

- Non-fasting individuals
  - presence of food in stomach (especially fatty foods) delays absorption
  - peak alcohol concentrations 1.0-6.0 hrs
- Alcohol ingested with carbonated beverages
  - ordinarily absorbed more rapidly than straight alcohol

Alcohol Distribution

- Alcohol has a high affinity for water
- Is diffused in the body in proportion to the water content of the various tissues & organs
  - greater concentration in blood & brain
  - lesser concentration in fat & muscle

Alcohol Distribution

- Absorbed alcohol is greatly diluted by the aqueous body fluids
  - 1 oz. (29.57 mL) of 50% (100 proof) whiskey will be diluted in a man of average build, to a concentration ~2 parts per 10,000 in the blood (0.02%)
Blood Alcohol Concentration

- BAC is the amount of alcohol in the bloodstream measured in percentages
  - BAC = 0.10%
  - means a person has 1 part alcohol per 1,000 parts of blood in the body

Blood Alcohol Concentrations

- A set of probable average curves of BAC in an average-size man after rapid absorption of various amounts of alcohol
- Shows rate of BAC decline over time as a result of metabolism & excretion

Elimination

- The liver eliminates ~95% of the alcohol through metabolism
  - oxidation via acetaldehyde & acetic acid to carbon dioxide & water
- Remainder of eliminated through excretion in breath, urine, sweat, feces, milk & saliva
- Rule of Thumb
  - 0.5 oz (15 mL) alcohol eliminated per hr

Elimination

- Absorbed alcohol is passed through the liver by circulating blood
- ADH (alcohol dehydrogenase) converts the alcohol to acetaldehyde
  - acetaldehyde is a highly toxic substance
- Aldehyde dehydrogenase converts acetaldehyde to acetate ion
- Acetate enters blood stream & is ultimately oxidized to CO₂

Elimination

- Both enzymatic reactions require a co-enzyme, NAD, which accepts a hydrogen from the molecule
- The temporary depletion of NAD by the first step limits the rate at which alcohol can be metabolized

- Curve a
  - drinking 2 oz alcohol each hr for 4 hours
  - BAC increase is cumulative because alcohol is consumed faster than it can be metabolized
- Curve b
  - drinking 8 oz all at once
BAC’s Affect Behavior
Alcohol in the bloodstream continually circulates to the brain

<table>
<thead>
<tr>
<th>BAC</th>
<th>Affect</th>
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<tbody>
<tr>
<td>0.04%</td>
<td>Feelings of contentment, happiness, relaxation</td>
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<tr>
<td>0.06%</td>
<td>Judgement somewhat impaired, Some loss of coordination</td>
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<tr>
<td>0.08%</td>
<td>Less able to make rational decisions, Muscle coordination &amp; driving impaired</td>
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<tr>
<td>0.30%</td>
<td>Loss of consciousness may occur, Breathing may stop (death may result)</td>
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Some Alcohol Statistics
- ~half of traffic injuries involve alcohol
- ~1/3 of fatally injured passengers & pedestrians have elevated blood alcohol levels
- ~half of homicides involve alcohol
- 1/2 to 1/3 of suicides involve alcohol
- CDC estimates ~30,000 unintentional injury deaths are directly attributable to alcohol

Alcohol & Driving
Relative Fatality Risk (drivers in a single vehicle crash)

- Concentrated attention, speed control, braking, steering, gear changing, lane tracking, judgment
  - BAC 0.05: 360 times more likely to be involved in a fatal accident
- Tracking relationship to centerline
  - BAC 0.10: 5 times
- Simple reaction time (such as reaction to brake lights ahead, emergency response)
  - BAC 0.10: 11.1 times
- Choice reaction time (such as decision to brake)
  - BAC 0.10: 1.4 times

Alcohol and Law
- The American Medical Association and the National Safety Council have been able to exert considerable influence in convincing the states to establish uniform and reasonable blood-alcohol standards.
- Between 1939 and 1964 a person having a blood-alcohol level in excess of 0.15 percent w/v was to be considered under the influence, which was lowered to 0.10 percent by 1965.
- In 1972 the impairment level was recommended to be lowered again to 0.08 percent w/v.
- Starting in 2003, states that have not adopted the 0.08 percent level will lose part of their federal funds for highway construction.
- To prevent a person’s refusal to take a test for alcohol consumption, the National Highway Traffic Safety Administration recommended an “implied consent” law.
- Adopted by all states by 1973, this law states that the operation of a motor vehicle on a public highway automatically carries with it the stipulation that a driver will submit for a test for alcohol intoxication if requested or be subject to loss of the license.
Alcohol in Blood vs Breath

- The ratio of alcohol in blood to alcohol in alveoli air is 2100 to 1
- 1 mL of blood will contain about the same amount of alcohol as 2100 mL of breath
- During the period of absorption, the alcohol concentration is higher in arterial blood than venous blood
  - breath test reflects alcohol conc. in the pulmonary artery (reflects what reaches the brain)

Alcohol and Circulatory System

- Humans have a closed circulatory system consisting of a heart, arteries, veins, and capillaries.
- Alcohol is absorbed from the stomach and small intestines into the blood stream.
- Alcohol is carried to the liver where the process of its destruction starts.
- Blood, carrying alcohol, moves to the heart and is pumped to the lungs.
- In the lungs, carbon dioxide and alcohol leave the blood and oxygen enters the blood in the air sacs known as alveoli.
- Then the carbon dioxide and alcohol are exhaled during breathing.

Respiratory System

- Volatile chemicals dissolved in the blood will be brought to equilibrium with the air in the lungs
  - fixed ratio between compound in breath & blood

The Breathalyzer

- Measures the alcohol content of alveolar breath
- Subject blows into a mouthpiece until 52.5 mL of alveolar breath has been collected
  - measures alcohol concentration of 1/40 mL of blood
- The alcohol in the blood is reacted with chromic acid

Breathalyzer

\[
2 \text{K}_2\text{Cr}_2\text{O}_7 + 3 \text{C}_2\text{H}_5\text{OH} + 8 \text{H}_2\text{SO}_4 \rightarrow 2 \text{Cr}_2(\text{SO}_4)_3 + 3 \text{CH}_3\text{COOH} + 11 \text{H}_2\text{O}
\]
Cr (VI) Cr (III)
absorbs at 420 nm

- Beer's Law
  - the concentration of Cr (VI) is directly proportional to the amount of 420 nm light light absorbed by the sample
- Measures the concentration of the unknown solution to the concentration of a standard sample
**Breath Tests for Alcohol**

- **Intoxilyzer**
  - Measures the infrared radiation absorption in a specific wavelength to confirm the presence of organic chemicals.
  - Detects only ethyl alcohol.
  - Requires suspect to blow into a mouthpiece to give a sample.

- **Alcosensor**
  - The alcohol fuel cell consists of a porous, chemically inert layer that is coated on both sides with a thin platinum layer.
  - Any ethyl alcohol present in the breath samples is converted to acetic acid.
  - A microprocessor measures the electrical current and converts the measured electrical current into a BAC.

**Field Testing**

- Law enforcement officers typically use field sobriety tests to estimate a motorist’s degree of physical impairment by alcohol and whether or not an evidential test for alcohol is justified.
- The horizontal gaze test, walk and turn, and the one-leg stand are all considered reliable and effective psychophysical tests.
- A portable, handheld, roadside breath tester may be used to determine a preliminary breath-alcohol content.

**Gas Chromatography Testing**

- Gas chromatography offers the toxicologist the most widely used approach for determining alcohol levels in blood.
- Blood must always be drawn under medically accepted conditions by a qualified individual.
- It is important that a nonalcoholic disinfectant be applied before the suspect’s skin is penetrated with a sterile needle or lancet.
- Once blood is removed from an individual, its preservation is best ensured when it is sealed in an airtight container after an anticoagulant and a preservative have been added and stored in a refrigerator.

**Role of the Toxicologist**

- Beyond the analysis of alcohol, the toxicologist is confronted with a maze of drugs and poisons.
- The toxicologist is originally presented with body fluids and/or organs and is normally requested to examine them for the presence of drugs and poisons.
- Without supportive evidence, such as the victim’s symptoms, a postmortem pathological examination, or an examination of the victim’s personal effects, the toxicologist is forced to use general screening procedures with the hope of narrowing thousands of possibilities to one.
Role of the Toxicologist

- In addition, the toxicologist is not dealing with drugs at the concentration levels found in powders and pills, having been dissipated and distributed throughout the body.
- Furthermore, the body is an active chemistry laboratory as few substances enter and completely leave the body in the same chemical state.
- Last, when and if the toxicologist has surmounted all of these obstacles, he or she must be prepared to assess the toxicity of the drug or poison.

The Analytical Scheme

- The forensic toxicologist must devise an analytical scheme that will successfully detect, isolate, and specifically identify toxic drug substances.
- Once the drug has been extracted from appropriate biological fluids, tissues, and organs, the forensic toxicologist can proceed to identify the drug substance present.
- Drug extraction is generally based on a large number of drugs being either acidic or basic.
- The strategy used for identifying abused drugs entails a two-step approach: screening and confirmation.

The Screening Step

- A screening test is normally employed to provide the analyst with quick insight into the likelihood that a specimen contains a drug substance.
- Positive results arising from a screening test are considered to be tentative at best and must be verified with a confirmation test.
- The most widely used screening tests are thin-layer chromatography, gas chromatography, and immunoassay.

The Confirmation Step

- Gas chromatography/mass spectrometry is generally accepted as the confirmation test of choice.
- The GC separates the sample into its components, while the MS represents a unique “fingerprint” pattern that can be used for identification.
- Once the drug is extracted and identified, the toxicologist may be required to provide an opinion on the drug’s effect on an individual’s natural performance or physical state.

The DRE

- The Drug Recognition Expert program incorporates standardized methods for examining automobile drivers who are suspected of being under the influence of drugs.
- To ensure that each subject has been tested in a routine fashion, each DRE must complete a standard Drug Influence Evaluation form.
- The DRE program usually cannot determine which specific drug was ingested.
- Hence, it is the production of reliable data from both the DRE and the forensic toxicologist that is required to prove drug intoxication.

Postmortem Toxicology

- Postmortem analysis
  - Investigates the presence of drugs, gases, metals, and other toxic chemicals in human fluids and organs
  - Determines their role, if any, in the death
- Begins with a case history of the deceased
- Includes age, sex, weight, medical history, medication before death, autopsy findings, drugs available to decedent, and interval between onset of symptoms and death
- Includes analyses for poisons as diverse as prescription drugs, drugs of abuse, chemical products, and gases
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<tbody>
<tr>
<td>□ Collection of postmortem specimens</td>
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<tr>
<td>■ All body fluids and organs in which chemicals might concentrate are collected during the autopsy.</td>
</tr>
<tr>
<td>■ Specimens should be collected before the body is embalmed.</td>
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<tr>
<td>■ In cases of decayed bodies, analysis may be done on bone marrow, fluid in the eye, or hair.</td>
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<td>■ Maggots feeding on the corpse have been tested for drugs and used as evidence.</td>
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<tr>
<td>■ The gastrointestinal tract is often analyzed first, followed by urine.</td>
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<tr>
<td>■ Analysis focuses on the tissues of organs where the concentration of drugs may be the greatest.</td>
</tr>
<tr>
<td>■ Specimens should be collected as soon as possible after death.</td>
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<tr>
<td>■ Presumptive testing is performed first to detect the presence or absence of drugs.</td>
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<td>■ A positive immunoassay test leads to a confirmation test (usually gas chromatography–mass spectrometry).</td>
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<td>■ Each compound gives a characteristic fragment spectrum.</td>
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<tr>
<td>■ A computer compares the sample’s spectrum to a reference library.</td>
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<tr>
<td>■ The toxicologist tests for an inorganic substance if the case study suggests poisoning.</td>
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<td>□ Interpretation of toxicological information</td>
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<td>■ The toxicologist must determine how the poison entered the body and whether enough poison was ingested to cause death.</td>
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<tr>
<td>■ The highest concentration of poison is usually found where it entered the body.</td>
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<tr>
<td>■ Toxicology analysis may be able to estimate when the poison was dispensed.</td>
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