Alcohol: Pharmacology, Toxicology and Medico-legal aspects
Outline

• Pharmacology and toxicology of alcohol
  • Absorption, distribution and elimination in the body
  • Stages of alcohol intoxication
  • Tolerance
• Alcohol in breath, blood, and urine
• Alcohol and driving impairment
• Effects of alcohol on memory
Types of Alcohol

- Ethanol (ethyl alcohol, grain alcohol)
- Methanol (methyl alcohol, wood alcohol)
- Isopropanol (isopropyl alcohol, rubbing alcohol)
- Ethylene glycol
Routes of Administration

- Topical
- Inhalation
- Intravenous injection
- Oral ingestion
Absorption

• Absorption of ethanol is by simple diffusion
• 25% of an ingested dose of ethanol is absorbed from the stomach
• 75% of an ingested dose of ethanol is absorbed from the small intestine
Factors affecting absorption

Alcohol concentration of the ingested beverage

- Optimal absorption occurs for beverages with alcohol concentrations between 10% alc. v/v and 30% alc. v/v
  - Beverages <10 % alc. v/v do not present as large a concentration gradient
  - Beverages >30% alc. v/v will irritate the gastric mucosa and increase mucous production
Factors affecting absorption

Physiology

- Changes in blood supply to the GI tract
- Changes in motility will affect the speed with which ethanol enters the small intestine
Factors affecting absorption

Presence of food in the stomach

- Food in the stomach will prolong gastric emptying time, resulting in a lower, delayed peak blood alcohol concentration
Effect of food on absorption

![Graph showing the effect of food on absorption. The graph compares blood alcohol concentration over time between an empty stomach and with food in the stomach. The graph shows a higher and more prolonged peak in blood alcohol concentration when food is in the stomach, indicating slower absorption.]
Distribution

- Alcohol is hydrophilic and will distribute into fluids and tissues according to water content.

- Total body water (TBW) or distribution factor (r) is dependent upon:
  - Age
  - Sex
  - Body weight

- \( r \) – distribution factor
  - for women \( r = 0.6 \) and for men \( r = 0.7 \)
Examples

**Effect of sex:**
- Man weighing 150 lbs
- Woman weighing 150 lbs
- Each consume 2 beer
- BAC of the man will be 57 mg/100 mL
- BAC of the woman will be 67 mg/100 mL

**Effect of weight:**
- Man weighing 150 lbs
- Man weighing 200 lbs
- Each consume 2 beer
- BAC of the lighter man will be 57 mg/100 mL
- BAC of the heavier man will be 43 mg/100 mL
Volume of distribution – „r” for women

<table>
<thead>
<tr>
<th>Mass, kg</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
<th>95</th>
<th>100</th>
<th>105</th>
<th>110</th>
<th>115</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.69</td>
<td>0.66</td>
<td>0.63</td>
<td>0.61</td>
<td>0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.70</td>
<td>0.68</td>
<td>0.65</td>
<td>0.63</td>
<td>0.60</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.72</td>
<td>0.69</td>
<td>0.67</td>
<td>0.65</td>
<td>0.62</td>
<td>0.60</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.73</td>
<td>0.71</td>
<td>0.69</td>
<td>0.66</td>
<td>0.64</td>
<td>0.62</td>
<td>0.59</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.74</td>
<td>0.72</td>
<td>0.70</td>
<td>0.68</td>
<td>0.66</td>
<td>0.64</td>
<td>0.61</td>
<td>0.59</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.73</td>
<td>0.71</td>
<td>0.69</td>
<td>0.67</td>
<td>0.65</td>
<td>0.63</td>
<td>0.61</td>
<td>0.59</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.74</td>
<td>0.73</td>
<td>0.71</td>
<td>0.69</td>
<td>0.67</td>
<td>0.65</td>
<td>0.63</td>
<td>0.61</td>
<td>0.59</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.74</td>
<td>0.72</td>
<td>0.70</td>
<td>0.68</td>
<td>0.66</td>
<td>0.65</td>
<td>0.63</td>
<td>0.61</td>
<td>0.59</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.75</td>
<td>0.73</td>
<td>0.71</td>
<td>0.70</td>
<td>0.68</td>
<td>0.66</td>
<td>0.64</td>
<td>0.63</td>
<td>0.61</td>
<td>0.59</td>
<td>0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.74</td>
<td>0.72</td>
<td>0.71</td>
<td>0.69</td>
<td>0.68</td>
<td>0.66</td>
<td>0.64</td>
<td>0.63</td>
<td>0.61</td>
<td>0.59</td>
<td>0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.70</td>
<td>0.69</td>
<td>0.67</td>
<td>0.66</td>
<td>0.64</td>
<td>0.63</td>
<td>0.61</td>
<td>0.60</td>
<td>0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.74</td>
<td>0.73</td>
<td>0.71</td>
<td>0.70</td>
<td>0.69</td>
<td>0.67</td>
<td>0.66</td>
<td>0.64</td>
<td>0.63</td>
<td>0.61</td>
<td>0.60</td>
<td>0.58</td>
<td>0.58</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Volume of distribution – „r” for men

<table>
<thead>
<tr>
<th>Mass, kg</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
<th>95</th>
<th>100</th>
<th>105</th>
<th>110</th>
<th>115</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.78</td>
<td>0.75</td>
<td>0.72</td>
<td>0.69</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.79</td>
<td>0.77</td>
<td>0.74</td>
<td>0.71</td>
<td>0.69</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.80</td>
<td>0.78</td>
<td>0.76</td>
<td>0.73</td>
<td>0.71</td>
<td>0.69</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.82</td>
<td>0.80</td>
<td>0.77</td>
<td>0.73</td>
<td>0.71</td>
<td>0.68</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.83</td>
<td>0.81</td>
<td>0.79</td>
<td>0.75</td>
<td>0.72</td>
<td>0.70</td>
<td>0.68</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.82</td>
<td>0.80</td>
<td>0.76</td>
<td>0.74</td>
<td>0.72</td>
<td>0.70</td>
<td>0.68</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.83</td>
<td>0.81</td>
<td>0.79</td>
<td>0.77</td>
<td>0.74</td>
<td>0.72</td>
<td>0.70</td>
<td>0.68</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.82</td>
<td>0.81</td>
<td>0.79</td>
<td>0.77</td>
<td>0.73</td>
<td>0.72</td>
<td>0.70</td>
<td>0.68</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.83</td>
<td>0.82</td>
<td>0.80</td>
<td>0.78</td>
<td>0.76</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
<td>0.70</td>
<td>0.68</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.83</td>
<td>0.81</td>
<td>0.79</td>
<td>0.78</td>
<td>0.76</td>
<td>0.75</td>
<td>0.73</td>
<td>0.71</td>
<td>0.70</td>
<td>0.68</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.84</td>
<td>0.82</td>
<td>0.81</td>
<td>0.79</td>
<td>0.78</td>
<td>0.76</td>
<td>0.74</td>
<td>0.73</td>
<td>0.71</td>
<td>0.70</td>
<td>0.68</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.83</td>
<td>0.82</td>
<td>0.80</td>
<td>0.79</td>
<td>0.77</td>
<td>0.76</td>
<td>0.74</td>
<td>0.73</td>
<td>0.71</td>
<td>0.70</td>
<td>0.69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• A – resorption phase – from 0,5 h to 1,5 h (average 1 h)
• B – equilibrium phase (several minutes)
• C – elimination phase ($\beta_{60} = 0,1-0,2 \% / h$)
According to Widmark’s equation, the maximum concentration of alcohol in blood $C_r \ (\%_0)$ is a function of several variables

$$C_r = \frac{A}{m \cdot r} = \frac{C_v \cdot V \cdot 0,789}{m \cdot r \cdot 100}$$

where

- $A$ – resorbed mass of alcohol [g]
- $m$ – body mass [kg]
- $r$ – volume of distribution (a constant), for women $r = 0,6$ and for men $r = 0,7$
- $C_v$ – concentration of alcohol in a drink [% vol.]
- $V$ – volume of an alcoholic drink [ml]
- $0,789$ – density of ethanol [g/ml]
TASK

Calculate

What is the concentration of alcohol in the blood?

70 kg woman drank:
- 250 ml wine 15% v/v
- or 100 ml vodka 40% v/v
- or 150 ml champagne 10% v/v
- or 500 ml beer 5% v/v
- or 10 ml spirit 96% v/v

90 kg man drank
- 250 ml wine 15% v/v
- or 100 ml vodka 40% v/v
- or 150 ml champagne 10% v/v
- or 500 ml beer 5% v/v
- or 10 ml spirit 96% v/v
TASK

Calculate

Blood alcohol concentration is 0,5 mg/ml.
Question: How much alcohol did I drink?
For calculations insert your body mass

What alcohol:

- wine 15% v/v
- vodka 40% v/v
- champagne 10% v/v
- beer 5% v/v
- spirit 96% v/v
Retrograde extrapolation, sometimes called estimating back, or relating back, is the process of applying basic principles of pharmacokinetics to arrive at an estimate of a person’s blood or breath alcohol result at a prior time based on a measured concentration at a later time.

\[ C_x = C_{t1} + \beta \cdot (t_1 - t_x) \]
Retrograde extrapolation

\[ C_x = C_{t1} + \beta \times t \]

C<sub>x</sub>  initial blood alcohol concentration (initial BAC)
C<sub>t1</sub>  measured alcohol concentration in blood
\( \beta \)  alcohol elimination rate 0.1-0.2 (mg/mL)
t  elapsed time (in hour)
The path of alcohol in the body

1. Mouth: alcohol enters the body.
2. Stomach: some alcohol gets into the bloodstream in the stomach, but most goes on to the small intestine.
3. Small Intestine: alcohol enters the bloodstream through the walls of the small intestine.
4. Heart: pumps alcohol throughout the body.
6. Liver: alcohol is oxidized by the liver at a rate of about 0.15 g/L per hour.

- Alcohol is converted into water, carbon dioxide and energy.
Alcohol Metabolism

• 5-10% of ingested ethanol is excreted
• Biotransformation occurs in the liver
• Commences as soon as EtOH is absorbed
• Alcohol dehydrogenase is primary enzyme
Ethanol $\rightarrow$ Alcohol dehydrogenase $\rightarrow$ Acetaldehyde $\rightarrow$ Aldehyde dehydrogenase $\rightarrow$ Acetic Acid $\rightarrow$ $\text{CO}_2 + \text{H}_2\text{O}$
Elimination

- **Elimination** of alcohol from the blood:
  - Follows zero-order kinetics
  - Ranges from 0.1-0.2 mg/ mL/hour
  - Average rate of elimination is 0.15 mg/ mL/hour
  - Is fixed and unaffected by:
    - **coffee**
    - **exercise**
    - **showering**
    - **sleep**
    - **eating**
    - **fresh air**
Fructose

• There is scientific agreement that fructose, glycine and alanine can increase the elimination rate of alcohol.

The action of fructose in the enhancement of ethanol oxidation has been explained through the production of a metabolite of fructose d-glyceraldehyde which provides increased NAD cofactor for the oxidation of ethanol.

• However – the required intake of fructose is so high that vomiting and abdominal pains result from the ingestion.
Effects of Alcohol on the Body

Possible long-term effects of Ethanol

Large consumption

- Brain:
  - Impaired development
  - Wernicke-Korsakoff syndrome
  - Vision changes
  - Ataxia
  - Impaired memory
  - Psychological
    - Cravings
    - Irritability
    - Antisociality
    - Depression
    - Anxiety
    - Panic
    - Psychosis
    - Hallucinations
    - Delusions
    - Sleep disorders

- Mouth, trachea and esophagus:
  - Cancer

- Blood:
  - Anemia
  - Alcoholic cardiomyopathy

- Heart:
  - Cirrhosis
  - Hepatitis

- Stomach:
  - Chronic gastritis

- Pancreas:
  - Pancreatitis

- Peripheral tissues:
  - Increased risk of diabetes type 2

Small to moderate consumption

- Systemic:
  - Increases insulin sensitivity
  - Lower risk of diabetes

- Brain:
  - Atrophy
  - Reduce the number of silent infarcts
  - Decrease risk of dementia

- Blood:
  - Increases HDL
  - Decreases thrombosis
  - Reduces fibrinogen
  - Increases fibrinolysis
  - Reduces artery spasm from stress
  - Increases coronary blood flow

- Skeletal:
  - Higher bone mineral density

- Joints:
  - Reduced risk of rheumatoid arthritis

- Gallbladder:
  - Reduced the risk of developing gallstones

- Kidney:
  - Reduced risk of developing kidney stones

Effects linked with both small and large consumption
Effects of Alcohol on the Body

- **Vasodilatation**
  - Creates a feeling of warmth when alcoholic beverages are consumed
  - Contributes to paradoxical undressing in hypothermia deaths

- **Disinhibition**
  - Responsible for the “stimulant” effects of alcohol
  - Euphoria, ↑ talkativeness, ↑ sociability
Effects of Alcohol on the Body

• Central nervous system depressant
  • Non-selective depression of brain and spinal cord
  • Effects occur on a continuum - with increased BAC, increased effects occur
  • Sedated → Sleepy → Stuporous → Unconscious
  • Effects are additive with other CNS depressants
Signs and symptoms of alcohol influence
## Stages of Alcohol Intoxication

<table>
<thead>
<tr>
<th>Subclinical</th>
<th>0.1–0.5 mg/mL</th>
<th>0.3–0.12 mg/mL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Slight intoxication</strong></td>
<td>May be no observable signs of intoxication</td>
<td><strong>Mild euphoria, ↑ sociability, talkativeness</strong></td>
</tr>
<tr>
<td><strong>Laboratory testing may reveal some effects</strong></td>
<td></td>
<td><strong>Increased self confidence, ↓ inhibitions</strong></td>
</tr>
<tr>
<td><strong>Sensory perception ↓ (e.g. hearing)</strong></td>
<td></td>
<td><strong>Loss of fine motor skills</strong></td>
</tr>
<tr>
<td><strong>Slowed information processing</strong></td>
<td></td>
<td><strong>Slowed information processing</strong></td>
</tr>
</tbody>
</table>
### Stages of Alcohol Intoxication

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9–2.5 mg/mL</td>
<td>- Emotional instability (dissatisfaction)</td>
</tr>
<tr>
<td></td>
<td>- Mental confusion</td>
</tr>
<tr>
<td></td>
<td>- Memory impairment</td>
</tr>
<tr>
<td></td>
<td>- Impaired balance and coordination</td>
</tr>
<tr>
<td></td>
<td>- Sedation, drowsiness</td>
</tr>
<tr>
<td>1.8–3.0 mg/100 mL</td>
<td>- Disoriented to time and place, ↑ confusion</td>
</tr>
<tr>
<td></td>
<td>- Exaggerated emotional state</td>
</tr>
<tr>
<td></td>
<td>- Double-vision</td>
</tr>
<tr>
<td></td>
<td>- Motor incoordination worsens, apathy</td>
</tr>
<tr>
<td></td>
<td>- Anesthesia</td>
</tr>
</tbody>
</table>
# Stages of Alcohol Intoxication

<table>
<thead>
<tr>
<th>Blood Alcohol Concentration</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5-4.0 mg/mL Stupor</td>
<td>Loss of motor function, Response to stimuli ↓, Stupor, unconsciousness, Vomiting, incontinence, Hypothermia</td>
</tr>
<tr>
<td>3.5-5.0 mg/100 mL Coma</td>
<td>Unconsciousness → Coma, Depression of reflexes, Impairment of respiration, circulation, more than 4.0 Death</td>
</tr>
</tbody>
</table>
Alcohol and Death

• Primary mechanism for death due to acute alcohol intoxication is respiratory depression

• Average BAC at which respiratory paralysis occurs is 3.5 mg/mL

• Death can occur at much lower BAC where aspiration of vomit occurs
Positional Asphyxia

• Alcohol intoxication is the major risk factor for positional asphyxiation. Central nervous system depression causes relaxation of the muscles that keep the airway open during sleep.

• Average BAC in 23 cases of positional asphyxiation was reported to be 2.4 mg/mL (Bell et al. 1992)
Tolerance

• Chronic use of alcohol will result in a decreased susceptibility to the effects of alcohol
  • Visible signs of intoxication are decreased
  • Increased survivability even after consumption of large amounts of alcohol

• Tolerance to alcohol may be either functional and/or metabolic in nature
Functional Tolerance

- Decreased sensitivity to the CNS depressant effects of EtOH
  - e.g. Integrity of phospholipid bilayer $\uparrow$
  - e.g. Up-regulation of excitatory receptors
- Requires higher BAC and higher doses of EtOH to produce the same effect
- “Learning” by the chronic alcohol user
Metabolic Tolerance

- Induction of enzymes in chronic, heavy users of alcohol can result in an enhanced metabolic rate
- Elimination rate in alcoholics has been measured at 40 mg/100 mL/hour and up
- Result is a comparatively lower BAC after equivalent doses of alcohol are ingested
Example: Tolerance


• Measured range of BAC in 65 patients who had been deemed “non-intoxicated” by examining physician
  • Ambulatory
  • Alert, capable of passing mental status exam
  • Responsible for self

• Blood alcohol concentrations ranged from undetectable to 540 mg/100 mL (average BAC was 268 mg/100 mL)
Alcohol in Blood, Breath and Urine
Alcohol in Blood

- Plasma and serum are the “watery” components of whole blood
- Plasma and serum therefore have a higher alcohol content than whole blood
- Plasma:whole blood ratio ranges from approximately 1.0 to 1.3. Average plasma:whole blood ratio is 1.14
Case Example

• An individual suspected of driving while impaired is brought to the hospital for medical treatment following a car accident in which his 2 passengers were badly injured

• Blood is drawn at the hospital for medical purposes and hospital laboratory results reveal a serum alcohol concentration of 17 mmol/L

• Police would like to know if they can charge this individual with driving over the legal limit
Over 80?

- 17.5 mmol/L → 0.8 mg/mL
- Serum:blood = 1.14
- Therefore, a serum alcohol concentration of 0.8 mg/mL indicates a whole blood alcohol concentration of 0.7 mg/mL
- This individual is not “over 0.8” at the time the blood sample is drawn
Alcohol in Urine

• Alcohol will pass from the blood into the urine as the blood is filtered in the kidneys.

• Urine contains approximately 1.3x as much water as blood, therefore the UAC will be 1.3 times that of the BAC.
Analytical Considerations

Ethanol losses during storage can occur by three mechanisms:

1. Diffusion from improperly sealed containers
2. Metabolism of ethanol by microorganisms
3. Oxidation of ethanol $\rightarrow$ acetaldehyde

Proper storage conditions will minimize the loss of ethanol
Analytical Considerations

- Neo-formation of ethanol during storage can occur if there is a source of microbial contamination and a suitable substrate for fermentation (e.g. glucose)
- More likely to occur in postmortem cases but can also occur in samples taken from living subjects
- Sodium fluoride will prevent the neo-formation of ethanol during storage
Example Case

- Woman, early 20’s
- Sexually assaulted
- Blood alcohol level = 0 mg/100 mL
- Urine alcohol level = 105 mg/100 mL
- Blood alcohol sometime prior to collection of the urine sample was 80 mg/100 mL
Further history…

- Non-drinker, mentally challenged
- Lived in a group home, no access to alcohol
- Poorly controlled diabetic
- Yeast infection

\[ \text{Sugar} + \text{Yeast} \rightarrow \text{Ethanol} \]

The woman had not necessarily been drinking; part or all of the ethanol detected in the urine may have been formed after collection of the sample.
Alcohol in Breath

• Alcohol is volatile - at physiological temperatures alcohol will diffuse from the blood into the alveolar air of the lung and into the breath

• Breath analysis is rapid, non-invasive, and does not require specialized medical personnel for sampling
Henry’s Law

- At a given temperature, the ratio of the concentration of a volatile compound in solution and the concentration of the volatile compound in the air above the solution is fixed.

$$\frac{C_{\text{ethanol in solution [promile = g/l]}}}{C_{\text{ethanol in air [mg/l]}}} = \frac{2100}{1}$$

- At 37°C, the amount of alcohol in the blood will be 2300x greater than the amount of alcohol in the end-expiratory breath.
Issues in Breath Testing

Quality of the breath sample

• End-expiratory breath is the best reflection of the alcohol content of the blood

• A “poor quality” breath sample will result in an underestimate of blood alcohol concentration
Issues in Breath Testing

*Mouth alcohol effect*

- Residual alcohol, temporarily trapped in the mouth may result in an elevated breath alcohol concentration

- Sources of mouth alcohol
  - Recent ingestion of alcohol
  - Regurgitation or vomiting
  - Asthma inhalers
  - Breath sprays and mouthwashes
Mouth alcohol effect

- Since the mouth alcohol effect will dissipate within 15 minutes, observation of a subject for a minimum of 15 minutes will protect against artificially elevated breath alcohol results.

- Duplicate breath testing is a further safeguard against mouth alcohol effect.
Mouth alcohol effect

• Since the mouth alcohol effect will dissipate within 15 minutes, observation of a subject for a minimum of 15 minutes will protect against artificially elevated breath alcohol results.

• Duplicate breath testing is a further safeguard against mouth alcohol effect.
Postmortem Ethanol

- It was proposed that agonal or postmortem aspiration of ethanol–rich vomitus and postmortem fermentation could account for the elevated concentrations in heart blood and bile; high vitreous ethanol could have resulted from diffusion in the agonal phase or postmortem.

- Ethanol can be formed by postmortem fermentation, degraded by bacterial action and redistributed within the body through trauma and other processes. Under appropriate conditions ethanol can be formed in concentrations up to 0.5-1.0‰ blood.
Postmortem Ethanol

- Ethanol can be present in postmortem blood as an artefact:
- **When the stomach contains** a sufficiently large amount of ethanol, the ethanol may **diffuse through the stomach wall and diaphragm** and eventually enter into the heart and central blood vessels. The presence of a small amount of beer or wine, such as might be left after a single drink with lunch, could produce an enormously elevated, but artefactual chest blood ethanol concentration.
- Another mechanism by which blood alcohol may be elevated is the **agonal, or postmortem, movement of gastric contents** into the trachea and lungs.
Analysis of Ethanol

- Field Sobriety Tests (at the roadside)
- Measurement of alcohol in breath (at the roadside)
- Measurement of alcohol content in blood (in a laboratory)
A typical scenario for procedures relating to DUI (driving under influence)

1. Police see a vehicle being driven erratically or are called to the scene of an accident.
2. Police question the driver and look for signs of impairment.
3. Police assess impairment using tests such as the horizontal gaze nystagmus test and walk and turn test.
4. Police carry out roadside screening tests for breath alcohol (BrAc) and/or drugs.
A typical scenario for procedures relating to DUI

5. If tests indicate the driver is over the legislative limit for BrAc and/or if drugs are present, the driver is taken to a police station or other authorised test facility and an evidential breath alcohol test carried out and/or a sample of blood taken for laboratory testing.

6. The blood sample is analysed for blood alcohol by headspace gas chromatography and for the presence of drugs if impairment through drugs is suspected.

7. The driver may be prosecuted depending on the test results and circumstances of the case.
Field Sobriety Testing

• Law enforcement officers use field sobriety tests to estimate a motorist’s degree of physical impairment by alcohol and to determine whether an evidential test for alcohol is justified.

• The horizontal gaze nystagmus test, walk and turn, finger and nose test and the one-leg stand are all considered reliable and effective psychophysical tests for alcohol impairment.
Field sobriety testing consists of a series of psychophysical tests and a preliminary breath test (typically done with a handheld fuel cell tester). These tests are preliminary and nonevidential in nature—they only serve to establish probable cause requiring a more thorough breath or blood test.
An object is held in front of the driver’s eyes. This is then moved to one side and then the other while the driver is asked to hold their head still and follow the movement of the object with their eyes. The officer observes the motion of the driver’s eyes. If the driver is not impaired through drugs or alcohol their eyes should follow the object with a steady gaze. If they are impaired, the motion of the eyes will be jerky and the driver may have difficulty keeping their head still with a tendency to move the whole head in order to track the object.
Walk & Turn test

The driver must walk along a real or imaginary line putting one foot directly in front of the other, heel to toe. They must take nine steps in this manner, counting out loud. When the ninth step has been taken they must leave the front foot on the line and turn around using a series of small steps with the other foot. After turning they must take another nine heel to toe steps along the line.
Finger and nose test

The driver stands with feet together, hands out in front palms side up and closed with the index finger extended. The officer then asks the driver to tilt their head back and he then calls out a sequence of left and right commands and the driver must touch their nose with the corresponding index finger and then lower their head.
Stand on one leg test

For this test the driver must raise the right foot six to eight inches off the ground and keep their hands by their sides. They must then count ‘one thousand and one, one thousand and two’ and so on until the officer tells them to stop. The officer checks whether the subject sways, hops, puts their foot down or raises their arms.
Breath Tests

• A breath test reflects the alcohol concentration in the pulmonary artery.
• One instrument used for breath tests is called *The Breathalyzer*.
• The Breathalyzer is a device for collecting and measuring the alcohol content of alveolar breath.
The Breathalyzer
The Breathalyzer Con’t

• The Breathalyzer traps 1/40 of 2100 milliliters of alveolar breath.
• Since the amount of alcohol in 2100 milliliters of breath approximates the amount of alcohol in 1 milliliter of blood—the Breathalyzer in essence measures the alcohol concentration present in 1/40 of a milliliter of blood.
Breathalyzer Con’t

• Once the alveolar breath is trapped it is allowed to undergo a chemical reaction:

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

<table>
<thead>
<tr>
<th>Potassium dichromate</th>
<th>Ethyl alcohol</th>
<th>Sulfuric acid</th>
<th>Chromium sulfate</th>
<th>Potassium sulfate</th>
<th>Acetic acid</th>
<th>Dihydrogen oxide</th>
</tr>
</thead>
</table>

• The Breathalyzer indirectly determines the quantity of alcohol consumed by measuring the absorption of light by potassium chromate before and after its reaction with alcohol, using the principle of spectrophotometry
Other Breath Tests

- Infrared breath-testing instrument
- Fuel cell
- Note: These instruments are used more recently because they don’t depend upon chemical reagents and are entirely automated.
Infrared-Breath Test

- Uses the principle that infrared light is absorbed when shined on alcohol
- Essentially, the infrared light passes through a chamber where it will interact with the alcohol and cause the light density to decrease.
- The decrease in light intensity is proportional to the concentration of alcohol present in the captured breath
Fuel Cell—Breath Test

• A fuel cell converts a fuel and an oxidant into an electrical current.
• In this test, the breath alcohol is the fuel and atmospheric oxygen acts as the oxidant.
• Alcohol is converted, generating a current that is proportional to the quantity of alcohol present in the breath.
Infrared and Fuel Cell Breath Tests

- **Infrared Breath Test** uses infrared wavelengths to test for alcohol or other interferences in the breath.

- **Fuel Cell Test** converts fuel (alcohol) and oxygen into a measurable electric current.
Other breath tester

Alkotest 7410 Plus

AlcoSensor IV

Intox 400
Alcohol test in saliva

Saliva Alcohol Test Strip is a semi-quantitative rapid test that detects the presence of ethyl alcohol in saliva at a level greater than 0.2 g/L.

This easy to use and inexpensive alcohol test will produce accurate results for your on-site testing.
Measurement of alcohol content in blood (in a laboratory)

Enzymatic method ADH

This quantitative test is based on the oxidation of ethanol to acetaldehyde by alcohol dehydrogenase (ADH) in the presence of nicotinamide–adenine dinucleotide (NAD) and is applicable to serum and plasma. Several commercial ADH kits are available and the test can be performed on routine clinical chemistry analysers.

NAD (dotted line) and reduced form – NADH (dashed line)
Measurement of alcohol content in blood (in a laboratory)

- Headspace Gas chromatography is often used in the determination of alcohol in blood or urine.

Gas chromatography (GC) is a powerful and widely used tool for the separation, identification and quantitation of components in a mixture. In this technique, a sample is converted to the vapor state and a flowing stream of carrier gas (often helium or nitrogen) sweeps the sample into a thermally-controlled column.
Gas Chromatography uses a stationary liquid phase and a moving gas phase (called a carrier gas) which flows through a stainless steel or glass column.

- Components separate by moving through the column at different rates.
- The retention time is how long it takes for a component to emerge from the column; the retention times of known and unknown substances can be compared.
Headspace

- Simple Definition
- 'Headspace' is the gas space above the sample in a chromatography vial. Volatile sample components diffuse into the gas phase, forming the headspace gas. Headspace analysis is therefore the analysis of the components present in that gas.
Headspace

• A headspace sample is normally prepared in a vial containing the sample, the dilution solvent, a matrix modifier and the headspace.

• Volatile components from complex sample mixtures can be extracted from non-volatile sample components and isolated in the headspace or gas portion of a sample vial.

• A sample of the gas in the headspace is injected into a GC system for separation of all of the volatile components.
Headspace Gas chromatography

Area of peak proportional to ethanol concentration in a sample

Internal standard (e.g., t-buthanol) reduces sample injection error in the GC/FID system
Driving under influence of alcohol or drugs.
Legal status

• The Road Traffic Act
  Dz. U. 2005, No 108, 20 June

• Act about Drug addiction counteraction
  Dz. U. 2005, No 79, 29 July

• The Ministry of Health Decree concerning the list of substances acting similarly to alcohol, and the conditions and the methods for carrying out examinations for the presence of these substances in the human body
  Dz. U. 2003, No 116, 11 June
The Road Traffic Act
Dz. U. 2005, No 108, 20 June

• BAC 0,2-0,5 mg/mL - „a state after use of alcohol”
• BAC more than 0,5mg/mL - „a state of drunkenness”
• a person in a state „after using substances acting similarly to alcohol”
Statutory alcohol limits for driving

0.0 mg per ml - Romania, Slovakia, Czech Republic, Croatia, Latvia, Lithuania, Hungary, Russia

0.2 mg per ml – Estonia, Malta, Poland, Sweden, Cyprus (South), Australia

0.5 mg per ml - Belgium, Bulgaria, Denmark, Germany (Germany is 0.3 if you’re in an accident), Finland, France, Greece, Italy, Serbia/Montenegro, Macedonia, Netherlands, Austria, Portugal, Slovenia, Spain, Turkey, Cyprus (North), Switzerland, Norway, Iceland

0.8 mg per ml – UK, Ireland, Luxembourg, Malta, USA, Canada,