

Forensic Toxicology: Death and Investigations – A Review

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Abstract: Deaths involving toxins account for a significant number of cases handled by forensic facilities.^[1] Some of these cases may be straightforward but in most of the cases, there is no indication of toxin exposure at autopsy, either on internal or external examination. A further difficulty arises at the scene as there may be no indications of drug usage. Thus, most drug-related deaths are included in the larger population of deaths that have "no anatomic cause of death". Occasionally, there are findings that give clues to a possible toxin-related death. This review outlines the procedures in investigation of toxin-related deaths.

Keywords: Toxicology, forensics, investigations, detection

1. Introduction

Toxicology is the study of the adverse effects of drugs and chemicals on biological systems.^[2]

Toxicology encompasses methods and procedures from many disciplines, including chemistry, biochemistry, epidemiology, pharmacology, pathology, and physiology.

Most often, knowledge acquired through these disciplines is applied to find answers to questions related to alcohol, legal/illegal drugs, poisons, metals, and gases.^[3]

Forensic toxicology is a highly specialized area of forensic science which requires expertise in analytical chemistry, pharmacology, biochemistry, and forensic investigation. There are primarily three sub disciplines of forensic toxicology:

- 1) Postmortem toxicology, more recently referred to as death investigation toxicology.
- 2) Behavioral or human performance toxicology, which concerns
 - a) Impaired driving as a result of alcohol and/or drugs consumption.
 - b) Drug-facilitated sexual assault cases.
 - c) Doping control. Screening of athletes for performance-enhancing substances is monitored by the World Anti-Doping Agency. In this category must be included equine and canine toxicology testing, because entire laboratories are dedicated to this specific purpose.
- 3) Forensic workplace drug testing or drug urinalysis, which is performed as a pre-employment and/or random monitoring of employees for illicit drugs or court ordered testing of convicted drug offenders.^[4]

Forensic toxicologists are concerned not only with the isolation and identification of drugs and other poisons from tissues, but also with the interpretation of his findings for the medical examiner, coroner, or other legal authority.^[5]

They perform scientific tests on bodily fluids and tissue samples. Their work environment is primarily in a lab using highly sophisticated instruments and precise methods. In addition to processing materials from crime scenes, the field has grown to include drug testing for employers, testing of

wildlife samples to identify criminal or natural causes of incidents, and athlete testing for performance enhancing substances. Some toxicologists also work on cases of environmental contamination or industrial accident. Based on the results of their investigation, forensic toxicologists draw conclusions and may serve as expert witnesses in court.

They work in both the legal and medical industries providing invaluable information on poisons for court cases. Within the medical field, a forensic toxicologist works within poison control centers throughout the United States providing information about the safety of food and drugs. The Environmental Protection Agency, the Food and Drug Administration, governmental health administrations, and the Consumer Product Safety Commission employ forensic toxicologists. Toxicologists also work with crime scene investigators providing information about substances that are involved. The knowledge provided by a forensic toxicologist can prove vital in determining the outcome of criminal cases.^[6]

2. Death Investigation Toxicology (Postmortem Toxicology)

Forensic toxicologists work with pathologists, medical examiners and coroners in helping to establish the role of alcohol, drugs and poisons in the causation of death. The toxicologist identifies and quantifies the presence of drugs and chemicals in blood and tissue samples. This is done using state of the art, chemical and biomedical instrumentation capable of detecting small amounts of toxic materials, positively identifying them, and accurately measuring how much is present. Accuracy, validity and reliability are essential, as this information is used in the determination of cause and manner of death. Those determinations are the prerogative of the medical examiner or coroner; however, the toxicologist is a key member of the team of experts that assist in that determination, consulting on pharmacology, drug kinetics and interactions, metabolism, adverse and idiosyncratic reactions, drug tolerance, postmortem artifacts, drug stability, and other factors. The pathologist considers this information in the context of the investigative and medical history of the case, and the findings of disease or other medical conditions at autopsy. Accurately establishing the appropriate cause and manner of death has serious implications for public health

and public safety, and forensically reliable toxicology is an essential component of that process. Death Investigation toxicology is performed by both public and private laboratories and many private forensic laboratories provide specialized expertise and services not available in government laboratories.^[7]

Sampling techniques: Every specimen must be taken with either a disposable or a clean, dry device. For the removal of body fluids, pipettes with a large diameter or syringes with needles of suitable width and length can be used. For more viscous samples, spoons or ladles; for smears, swabs; for tissue, scalpels, knives or scissors; for gasses, so-called “gas mice” or gas-tight syringes can be used.^{[8] [9]}

Preservation of specimens:^[10] Optimally, one blood sample should be collected with a final concentration of 1-5% sodium fluoride, and one in parallel without. For determination of alcohol in vitreous / aqueous humor, addition of sodium fluoride is also recommended. All other samples should be collected without additives.

Blood: Blood from the femoral vein, or other peripheral veins after preparation of the veins via puncture or incision; where necessary separate sampling of blood from left and right veins; removal of heart blood after opening of the pericardial sack via puncture or incision of the cardiac cavities.

Urine: Via puncture or directly from the bladder with unhindered view after opening of the abdominal cavity.

Gall bladder fluid: By squeezing contents into a container; aspiration with a needle after opening the abdominal cavity is seldom effective due to the normally highly viscous contents.

Cerebrospinal fluid: Suboccipital puncture, or – less recommended – aspiration from the brain’s ventricle system after removal of the skull, or via lumbar puncture.

Vitreous humor: Via a syringe with a fine needle after puncturing the anterior eye cavity, thereafter replacing the fluid removed by an appropriate amount of saline.

Gastric contents: After opening the abdominal cavity, the stomach should be tied off and then removed, subsequently emptying the contents into a container and documenting the total amount. Suspicious items such as tablet remnants and herbal matter etc. should be isolated, dried (e.g. on cellulose tissue) and stored separately. If the contents are nonhomogeneous, then preferably the whole stomach contents should be collected.

Tissue specimens: Sampling in separate containers. For cases of poisoning where gaseous or volatile substances are involved, samples of brain, lungs and blood must be collected immediately using gas-tight containers, and if possible, tarred, cooled glass containers. In the presence of penetrating substances or putrefaction, separate removal of portions of the liver near to and far away from the stomach should be done.

Smears: Wiping off of suspicious parts of the skin or mucosa with a cotton wool pad or another suitable adsorbent; in cases of drug death, another area of the skin covered by clothes is wiped off. The adsorbent can be moistened with methanol or another suitable solvent if needed.

Hair samples: Removal is performed preferably from the posterior vertex region of the scalp, except those areas which have come into contact with blood, vomit or putrefaction fluid. A tuft of hair roughly the thickness of a pencil is firmly tied together, and cut off as close as possible to the scalp under light tension. The stubble of hair remaining at the collection site should be noted. Moist hair must be dried. Body hair is removed with a disposable razor or scalpel.

Bone specimens: A piece of cancellous bone (3-5 cm) for example from a vertebra, and a ca. 3-5 cm piece from the femur. **Entomological specimens:** As maggots excrete drugs they have taken up very soon after removal from their source of food, they should be briefly washed and frozen immediately after their capture.

Collection of evidence from the scene: Remnants of drinks, fluids or other suspicious materials should be transferred to unbreakable, leak-proof containers and should be packed separately from each other, including the original container itself. All solid matter or containers should be packed separately so as to avoid risk of injury. Gases or vapors can be sampled with a “gas mouse”, or, in the case of an analysis being able to be performed quickly, with a gas-tight syringe. Alternatively, the gas can be transferred from the syringe into a headspace vial.^[8]

The first necessary component of the testing process is to demonstrate the validity of test specimens. This demonstration is accomplished through the chain of custody, which documents the chronologic disposition and condition of specimens from the time of collection to the time of disposal. The person initiating the chain of custody would typically provide the identity of the individual from whom the specimen was collected, what the specimen is, when it was collected (time and date) and by whom, including signatures. Tamper-evident tape with initials across the tape may be used to help maintain the integrity of the specimen. As the specimen moves through the transfer and testing process, printed names and signatures of releasing and receiving persons are recorded as are the time and date, the condition of the specimen, and the reason for transfer. Without correct, legible, and intact chain of custody documentation, the integrity and security of the specimens cannot be established, and the results of toxicology testing may be judged to be inadmissible to the court. The chain of custody form is often combined with the toxicology request form into a single document. The toxicology request form allows the selection of specific testing batteries such as a volatile screen, drug of abuse screen, comprehensive analysis, or other special testing requests.^[11]

Standard testing battery within a forensic toxicology laboratory will include an alcohol (volatile) screen, a drug of abuse screen, electrolyte profile, and a comprehensive analysis. All screens include confirmation and quantitation of any positive results. Volatile analysis is most commonly

performed by gas chromatography (GC), whereas drug of abuse screens are performed with immunoassay. Immunoassay is continually expanding to allow screening for tricyclic antidepressants, salicylate, acetaminophen, methadone, oxycodone, barbiturates, carisoprodol, promethazine, and other drugs. Some laboratories are transitioning to use of high-performance liquid chromatography (HPLC)/mass spectrometry (MS) for drug of abuse screens. Confirmations are most often performed by GC/MS analysis with or without derivatization of analytes or with HPLC/MS/MS, if this instrument is available.^[12]

The typical matrix for workplace or court-ordered drug testing is urine, although use of alternative matrices (sweat, hair, and/or saliva) is being examined to with increasing frequency. Behavioral toxicology most frequently is performed on blood and/or urine specimens. Blood for forensic analysis is collected in gray top tubes containing the antimicrobial additive sodium fluoride and potassium oxalate as an anticoagulant. In that results may be presented in court, collection of blood in gray top tubes is an important forensic consideration. An often used defense strategy is to question the integrity of the specimen from the standpoint of in vitro production of ethanol. This argument is moot if the specimens are collected in gray top tubes and refrigerated. Interpretation of impairment from drug levels in urine is not possible, although some states have per se driving laws based on the concentration of drugs in urine. Whether the individual was under the influence of drugs or not cannot be established from urine results; all that can be reasonably known is that the individual was exposed to the drug.

Considerations for blood clots are similar for hospital specimens. If the decedent arrived at the hospital and admission specimens were collected, these are the most important specimens to analyze to obtain a valid interpretation of drug or alcohol contributions to the cause of death. Conversely, if admission specimens are not available and the hospital record reflects an extended hospital stay and/or transfusion/hemodilution, performing toxicology on postmortem specimens may be judged to be of little value. If family members indicate that they believe the hospital caused their loved one's death, then it is important that the laboratory analyze both admission blood and postmortem blood. Most hospitals keep collected specimens for a short time before they are discarded. Blood banks may hold specimens for a longer period than the hospital. Death investigators are trained to act quickly to recover hospital specimens, if they are available. In some situations, hospitals may work with coroner/medical examiner offices to preserve blood when a medico legal investigation is expected.

3. Conclusion

To fully understand a cause of death and to be able to answer all potential questions, it is often necessary to review far more than the autopsy report and associated photographs. A common request is assisting a client to understand if a person who died quite some time after sustaining an injury actually died as a consequence of that injury. In order to establish a clear, unbroken link between the injury and the death it is necessary to review all of the intervening events. Many times this type of case requires a review of many weeks to months to years' worth of documentation to establish such a link.

Sometimes this information may not have been available to the original pathologist for various reasons and a full review of these records may not actually occur until charges have been filed.

Generally, the Pathologist wishes to review the autopsy report and photographs, scene photographs, medical records, selected police reports, witness interviews (as appropriate; preferably audio/video recordings and transcripts), transcripts of appropriate sworn testimony (as appropriate) and toxicology reports at a minimum in the typical case. Obviously this list can be tailored to the individual case.

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