# Technology Management in Forensic Science

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## ABSTRACT

This article outlines some of the recent advances in biotechnology, analytical science, and clinical practice that are now being widely applied to forensic studies. Highlighted in this paper are a number of chemical and biochemical assays and pathway identifications, which have now become instrumental to fundamental criminal and forensic investigations throughout the world.

(Key Words: genetic identification, DNA fingerprinting, crime studies, medicolegal studies, toxicology, forensics)

## INTRODUCTION

Forensic science has become an ever-expanding branch of applied sciences; instrumental not only to unraveling the mysteries of crime, but also to supporting criminal, civil and regulatory laws. Even non-litigious matters can be resolved by using forensic science. Recent advances in science and technology have created a significant impact in evolving trends in this field. The absence of sperm in the vagina of a rape victim no longer means that a rapist goes free since, methodologies to profile for $P^{30}$ aminopeptidase are now available to point to the time of rape (Stubbings and Newwall 1985). The visualization towards growth, development and popularization apparently comes from some of the important strides made in forensic science. A few examples are presented in Table 1.

***Table 1: Important strides in forensic science.***

| | From: | To: |
|---|---|---|
| 1 | The small magnifying lens of "Sherlock Holmes" | Sophisticated scanning electron microscopes |
| 2 | Analgesics | Designer drugs |
| 3 | Calculators | Computers |
| 4 | Blood group typing | DNA typing |
| 5 | Fire crackers | High explosives |
| 6 | Drug toxicity | Toxicogenetics |
| | | |

| | | |
|---|---|---|
| 7 | Finger print powder | Laser beams |

## INTEGRATION OF FORENSIC SCIENCE WITH HEALTH CARE SYSTEMS

Several technological achievements made in the health sector including magnetic resonance imaging (MRI), positron emission tomography (PET scanning), and scanning electron microscopy (SEM) have also found their applications in forensics (Table-2). MRI is used to visualize the trajectory of the bullet, wound track, and direction of the thrust within the body, which provides vital evidence in cases involving firearms, and other sharp edged metallic weapons.

***Table 2: Application of different technologies from the health care sector to forensic science.***

| Technology | Application in health care system | Application in forensic science |
|---|---|---|
| MRI | a) Detection of various chemicals that occur naturally in the body such as phosphorous<br>b) The flow of biochemical energy in an organ | Mapping the trajectory of a bullet in the body, wound track, direction of thrust |
| PET scanning | Anatomical and functional abilities (biochemical and cellular) of the heart and other organs | Investigating the cause of death in cases involving the use of electrical equipment |
| SEM | Changes in the nuclei of skin cells and their origin | a) Analysis of GSR on the hand of the shooter<br>b) Detection of un-detonated particles in post-blast residues |

In patients with craniocerebral, maxillofacial, cervical, and spinal gunshot wounds, computed tomography (CT) was found useful to plan adequate treatment and solve complex medicolegal problems. Emergency CT was found to demonstrate the mechanism of the injury, the bullet path and site, the location of bone and/or metallic fragments, and damage extent. In injury monitoring, CT showed injury evolution, retained fragments, and complications, thus enabling damage extent assessment. High Resolution Computed Tomography (HRCT) was useful in locating minute orbitary retrobulbar and intra-spinal fragments. Magnetic Resonance Imaging (MRI) in postoperative patients proved a valuable tool to assess the extent of spinal cord damage (Scialpi et al. 1996).

The postmortem magnetic resonance images complemented the standard pathologic examination of the brain and spinal cord. The compelling advantages of postmortem radiographic procedure included the three dimensional aspects of the images; the ability to detect mineral (i.e., iron) deposits, small focal lesions such as hemorrhages or infarcts; and the ability to evaluate the extent of cerebral edema. Furthermore, due to its archival potential for documenting the topographic distribution of pathologic processes, this technique has great promise for forensic cases. The recently available high field-strength imaging brought the resolution of magnetic resonance to the microscopic-level and reaffirmed the potential value of magnetic resonance imaging for diagnostic and investigative studies in which both the histologic and fine radiologic features of lesions are of interest (Boyko et al. 1994).

PET-scanning provides an exact analysis of the anatomy as well as biochemical, cellular, and functional abilities of brain, heart and other organs. The information obtained is very important in resolving the cause of deaths in cases involving electricity, lightning, or accidents during the use of electrical appliances.  A special computer controlled positron camera may provide the picture of trace elements in body organs primarily in the heart and brain, which may be of high evidentiary value to determine the failure of functional activity of an organ.  The major advantage of this technology is that the patients need not to be exposed to the risks of instrumentation (Lewis 1987).

SEM is an excellent tool to analyze a wide variety of samples ranging from paint flakes to gunshot residues (GSR) deposits on the shooter's hand (Wolten 1979, Moreton 1996).  The gun shot residues available on the web portion of the shooter's hand is removed with a piece of adhesive tape and that tape is examined under SEM for the presence of particles that may have originated from the bullet, propellant, or primers.  The SEM characterizes the primer particles by the size, shape, and chemical composition.  The SEM can successfully distinguish the particles emanated from bullets and primers from that of those of other contaminants present on the hand of shooter.  When SEM is linked to an X-ray analyzer an elemental profile of the particles can be formulated (Warren and Tillman 1987).  Perhaps the use of this methodology can also be extended to the study of undetontated particles of explosives in post blast residues (Beveridge 1998).  The use of SEM with energy-dispersive X-ray spectrometry (EDS) in forensic analysis including accidents and analysis of alleged murder weapons in criminal investigations was also found to be highly informative (Geneulu 1995).

Besides their vital application in drug analysis and monitoring, techniques such as gas chromatography, high performance liquid chromatography, mass spectrometry and scanning electron microscopy earned their place in forensic analysis.  The combination of such methods has successfully been used for the analysis of both organic and inorganic components of cartridge discharge residues (Speers et al. 1994, Chasin and Midio 2000).

DNA from epidermal cells attached to the adhesive tape of stubs employed to collect and identify gunshot residue (GSR) with scanning electron microscope (SEM) was extracted, amplified with a polymerase chain reaction (PCR), and typed.  The method allows identification of specimens when attribution to a definite person was uncertain.  It was suggested that adhesive tape could be used as a non-invasive method for obtaining biological material suitable for DNA analysis from the skin surface (Torre and Gino 1996).

In health care SEM is used to study and verify the changes that occurred in the nuclei of skin cells that may be deformed and clumped with chromatin. In some cases the changes specific for electrical lesions were confirmed to be of thermal origin by using SEM techniques to investigate the metallic deposits (copper, aluminum and zinc).  Similarly changes produced in cases of death by respiratory paralysis or cardiac arrhythmias were unambiguously differentiated by using SEM.

Cerebrospinal fluid (CSF) markers provide useful information about the extent of brain damage. These biochemical indices may also be used when postmortem histopathological examination does not confirm antemortem brain insult. The testing of biochemical markers could be a reliable indicator of the degree of brain insult in support of morphological studies (Vazquez et al. 1995).

## METABOLIC TOXINS

Because of the wide use of pesticides for domestic and industrial purposes, the evaluation of their toxic effects is a major concern for public health. Acute pesticide poisoning is a major cause of morbidity and mortality (Lee et al. 1999). Most asphyxial deaths due to pesticide consumption result from respiratory failures. Since a large number of synthetic compounds are being introduced into the market for their use as pesticides, the task of evolving correct diagnosis, mode of management, and treatment has undergone a sea of changes. A careful study into the mechanism of toxicity reveals that the pathway resulting in death might differ from one compound to another. By examining this phenomenon even the time of death may be concluded. Therefore, the nature of metabolites, the pathway of their formation, and their half-life are very essential not only to evolve a precise cause and time of death, but also to manage the cases of acute toxicity.

Organo-phosphorous insecticides are the most toxic and frequently used in poisoning. The mechanism of toxicity and clinical manifestation of organo-phosphorous, carbamate, and organo-chlorine insecticides differ among themselves leading to the difference in the pathways resulting in death. While the cholinergic signs and symptoms of organo-phosphorous and carbamate insecticides appear to be similar, they are onset by different routes necessitating the requirement of different systems of management and treatment. Organo-chlorine insecticides are neurotoxins and affect membrane related enzymatic reactions adversely, resulting in abnormal electrical activity. This class of insecticide produces liver necrosis and sensitization of the myocardium to catecholamines as distinct features (Narahashi 1979).

Cooper et al. (1999) reported that pesticides alter gonadotropin secretion through a disruption of hypothalamic mechanisms, which may lead to adverse effects.

Pesticides may severely impair immune functions (Coccia et al. 1999) and the association between autoimmune diseases and pesticide exposure has more recently been suggested (Vial et al. 1996). Voccia et al. (1999) reviewed the immunotoxic effects of pesticides including histopathologic effects in immune tissues and organs, cellular pathology, altered maturation of immunocompetent cells, changes in B and T cell subpopulations, and functional alterations of immunocompetent cells.

Evaluation and management of drug toxicity has now become a complex problem that requires adaptation of appropriate technology followed by an understanding of genetics and polymorphism. In recent years, the term ‘pharmacogenetics’ or ‘toxicogenetics’ has entered into the toxicologist’s vocabulary. Pharmocogenetics describes different individuals' responses to drugs and chemicals that are related to heredity influences. For example the acetylation of an anti-tuberculosis drugs isoniazid (INH), antihypertensive agent hydrazine, and anti-arrhythmic drug procainamide is a metabolic process catalyzed by N-acetyltransferase

(Guttrendorf and Wedlund 1992). The genetic polymorphism controls the rate of acetylation and slow acetylators are prone to peripheral neuropathy from INH. It is the concentration of the un-metabolized drug in slow acetylators, which controls the adverse effects.

The hydrolysis of succinylcholine is controlled by an enzyme in plasma; 'plasma cholinesterase' (formerly known as pseudo cholinesterase) (Smith et al. 1989). The rate of hydrolysis is genetically dependent. Therefore, genetic differences lead to changes in the concentration of succinylcholine and consequently variations in the degree, rate, and magnitude of adverse effects.

Glucose-6-phosphate dehydrogenase (G6PD) deficiency is the most common inherited enzymopathy affecting approximately 400 million people. G6PD is the principal enzyme required to protect the red blood cells from the adverse effects of oxidants (Beutter 1991). The main clinical complication associated with G6PD deficiency is haemolysis after ingestion of oxidant drugs (anti-malarials, sulfonamides, analgesics, nitrofurans) and consumption of fava beans (Eichelbaum and Evert 1996). The discovery of genetic polymorphisms of drug metabolizing enzymes (e.g. N-acetyltransferase 2 and cytochrome P450 enzymes CYP2D6 and CYP2C19) has provided an explanation as to why some patients do not obtain the expected drug effects or show exaggerated drug response and serious toxicity after taking the standard and recommended dose of a drug. The different degree of inheritance of these enzymes is genetically dependent. The genetically related responses are presented in Table 3.

***Table 3: Pharmacogenetic differences in response to selected drugs.***

| **Differences in responses to selected drugs** | | |
|---|---|---|
| **Genetic Abnormality** | **Drug/Chemical** | **Response** |
| N-acetyl-transferase deficiency (Slow acetylators) | Isoniazid (anti-TB)<br>Procanamide (anti-arrhythmic) | Enhanced toxicity, the quality and quantity depend on the concentration of the parent drug. |
| Pseudocholinesterase deficiency | Succinylcholine | Prolonged skeleton muscle relaxation, apnea |
| Glucose-6-phosphate dehydrogenase deficiency | Quinine, Acetyl salicylic acid, Doxorubeil | Hemolytic anemia |
| Increased delta amino levulinic acid synthetase | Barbiturates | Hepatic porphyria |

## GENETIC ANALYSIS

The gene is a fundamental unit of heredity. Each gene is composed of DNA specifically designed to carry out single body function. The genes are also directly responsible for the production of proteins and chemicals essential for life. The forensic serologists are in a position to precisely say whether a small speck of blood belongs to a person or not, without any ambiguity. The same degree of expertise is also available to individualize a person from the remnants of the body. The ability of the PCR technique to amplify small quantities of a suspect's DNA present at the crime scene has the potential to revolutionize the analysis of biological evidence. The developments in DNA technology are so rapid that in the next 3-4 years it is likely that DNA analysis will become much simpler, less costly, and even more sensitive.

Blood group genotyping becomes essential to solving complex problems. In sexual assaults, one key to identifying the suspect is ABO phenotyping or the typing of other polymorphic markers of the seminal fluid in the victim's vagina. However, ABO phenotyping was frequently found to be unsuccessful, since mixtures of fluids could not be separated by conventional methods for the detection of antibody or antigen material. Recent studies included ABO blood group genotyping of sperm DNA isolated from contaminating vaginal fluid by the polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) method. Seminal samples of genotypes OO, AO, BO and AB mixed with vaginal fluid (OO, AO, BO and AB) could successfully be separated and genotyped by this method. The ABO genotyping method by PCR-RFLP using separated sperm DNA is considered more reliable in forensic identification in sexual assaults (Shiono 1996; Sasaki and Shiono 1996).

## CONCLUSIONS

DNA-based technology is gaining importance not only in forensics but also in some of the important areas of health care, like diagnosis through gene mapping and curative treatments by either cell fusion or cell cloning. Additionally, researchers are now being to find the genetic flaws that lead to diseases, and use them to fight the illness at its molecular source. Eventually such research will be associated with the development of appropriate technologies to identify the flaws in DNA, which have led to diseases, and also to cure them by injecting the correct copy of the gene into the patient.

The current trend to strengthen forensic science includes the use of computers for the processing of information, record-keeping, and risk management. These sophisticated systems are now available to provide vital decision support and open a new era leading to better management and strategic planning of forensic data.

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