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Challenges to Forensic Medicine in the Postmodern Era- the Impact of the New Technologies

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Abstract: Technology is in a quasi-permanent evolution in most professional areas, which has the potential to improve people's lives. The new technologies are already part of our lives, being able to create facilities which we would not even imagine it could be possible relatively little time ago. Forensic medicine did not move backward from implementing the new technologies, being in this way an important support for justice as the assessment is more accurate and more valuable, the offenders are sentenced, the innocents are exonerated, and victims in mass disasters are quickly identified. In this paper the authors analyze the impact the new technologies have in different areas of forensic medicine, such as forensic toxicology- particularly using GC-Ion Trap MS and LC-MS technologies, forensic imaging applied to post-mortem examination- using virtopsy and forensic genetics- the use and permanent refinement of DNA technology. The authors highlight, on the one hand, the improvements the new technologies brought in justice and society, and on the other hand the challenges associated with their implementation.

Keywords: *forensic, new technologies, toxicology, virtopsy, DNA, challenges.*

Introduction

“Innovation” means both a novelty created as such, original, and also an improvement applied to some already existing projects, when they need to face the evolution of humanity, new requests, incoherent or existing market needs and it covers alike ideas, devices, processes, services (www.omicsonline.org/pathology/forensic-pathology-innovations.php).

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In the support of scientific findings to innovation supervenes technology, which may be considered an essential stimulus in this regard, helping the new scientific findings to be a real benefit to society. The new technologies bring with them risks and the threat of abusive use, which demands the careful assessment of their risks and benefits, in order to ascertain the improvement of the quality of life (Kloosterman *et al.*, 2015).

Forensic medicine followed the ascending trend of the evolution of technology in life sciences adjusting the technologies in other domains or related auxiliary technologies.

High-tech equipments, often expensive, allow the forensic experts to practice their work so that forensic evidences provided to court, being of high quality, to lead to the elucidation of criminal cases and taking the fairest decision (Kloosterman *et al.*, 2015; Velnic *et al.*, 2017).

Forensic toxicology- the field of Nobel Prize innovations

In the field of toxicology, forensic pathology uses Nobel Prize innovations, which lead to an increased reliability of the evidences and to an increased contribution in the solution of criminal investigations.

“Quadruple ion trap” concept, carried out by Wolfgang Paul- for which he shared Nobel Prize in Physics in 1989- was taken over by forensic medicine within GC- Ion Trap MS (GC-ITMS) technology by George Stafford *et al.* This represented an important way to increase the sensitivity for detection of various substances. The advantages of ITMS are connected to its ability to examine various ions with an improved sensitivity (Smith *et al.*, 2007).

Thirteen years later, in 2002, John Fenn and Koicki Tanaka won the Nobel Prize in Chemistry for electrospray ionization, applied in forensic field in the LC-MS technology, which lead to an improvement and the widening of its application (Smith *et al.*, 2007). LC technology is based on dissolution of the analytes and their separation based on differences in solubility between the two phases: mobile (liquid) and stationary (small solid particles). Improvements in the last decades of the 20th century in the methods of LC, assume smaller diameters of the solid particles and pumps which are capable to produce a higher pressure with uniform flow (Smith *et al.*, 2007).

The two technologies described above created multiple uses in forensic medicine, and allow the identification and quantification of a large

number of products from biological fluids (small molecular weight drugs, steroids and toxins, and even macromolecules) (Smith *et al.*, 2007).

Overall, advantages of new technologies in forensic toxicology concern various aspects such as: improvement of ruggedness which made it useful in hair analyses, blood and soft tissues; decrease in the time required for analysis; simpler and faster procedures due to the new designs of the software; increased veracity of the findings; increase in the resolution and precision; decrease in the limit of detection; possibility to widen the expertise of the toxicology laboratory due to better quality of the sample and, finally, increased reliability of the evidences provided to justice (Smith *et al.*, 2007; Gorun *et al.*, 2010).

Virtopsy- the use of complex imaging methods in forensics

In order to document as better as possible the evidences required in court, it is mandatory for the forensic pathologist to use in his practice the imagistic devices, especially because the images may be reassessed or analyzed by an independent expert if needed (National Research Council, 2009).

Currently, forensic medicine uses a number of imagistic methods, routinely employed by clinicians (Badam *et al.*, 2017; Petre-Ciudin *et al.*, 2017), both in establishing the cause of death and in the livings in order to assess the injuries in the deep soft tissues or to accurately assess marker lesions (e.g. biting injury) (Scripcaru *et al.*, 2007; Bollinger, Thali, 2015; Benghiac *et al.*, 2017).

Employing imagistic technologies in forensic practice started with the external examination of the body with 3D photogrammetry-based optical surface scanning, technology which offers the possibility for a comprehensive research of the body surface, but also of the deep tissues and by internal examination using CT- which enables the identification of bone injuries, foreign bodies, fluid accumulation as well as the distribution of the gas and using MRI- optimum in the analysis of the organs and soft tissues. These methods have been supplemented over the years by angiography which allows the assessment of the cardiovascular system using a peristaltic pump and the contrast solutions, allowing the estimation of the occlusion and of the rupture of the blood vessels and imaging guided biopsy- which allows to collect samples for laboratory analysis (toxicology, histology, bacteriology, virology) without the risk of contamination (Bollinger, Thali, 2015).

In the field of forensic imaging, the latest innovation is the Virtopsy® project, realized at the beginning of the 1990s by a Swiss research

team conducted by Thali, who put together the abilities of the CT and MRI (Bollinger, Thali, 2015), scanning and radiological methods with the potential of the computers (Badam *et al.*, 2017), complemented by minimally invasive techniques such as angiography and biopsy (Bollinger, Thali, 2015). In the same time, it is a „multi-disciplinary technology that combines forensic medicine and pathology, roentgenology, computer graphics, biomechanics and physics” (Badam *et al.*, 2017).

For the setup of the name they began with the “autopsy”, a combination of the Greek “autos” (self or with one’s own) and “opsomei” (seeing eyes), the whole meaning “see with one’s own eyes” (Thali *et al.*, 2017)- from which they excluded the subjectivity of “autos”, keeping only “opsomei” (Badam *et al.*, 2017) and the “virtual” term, the Latin word for “useful, good and efficient” (Thali *et al.*, 2003, Badam *et al.*, 2017). Thus, the mission of the new technology was an objectively documentation through the analysis of the “physical features and evidence” (Thali *et al.*, 2003). The construction of this new concept was made possible as a consequence of the impressive development of the already existing imaging technologies. Nevertheless, even the imaging methods were already used in forensics until that time, Swiss team was the first to conceive the practical benefit of their fusion (Thali *et al.*, 2003, Badam *et al.*, 2017). They thus succeeded to create a method for an objective, reproducible and minimally invasive forensic assessment. On a scientific level, Virtopsy project meant valuable publications, while for the industry meant important financial gains (Thali *et al.*, 2003).

Virtopsy meant an important forward step in the examination of human bodies and brought undeniable benefits in this field. Virtopsy represents a genuine help in establishing the cause and manner of death, without affecting the body integrity (Badam *et al.*, 2017, National Research Council, 2009). This “virtual preservation” of the body induces a decrease in the number of autopsies, an important issue when religious issues come forth (National Research Council, 2009; Ioan *et al.*, 2012). It allows an effective assessment of some important items in a short period of time, involving more experts in specific subspecialties in order to obtain an optimal analysis, with the possibility to replay the scans (Badam *et al.*, 2017; Bollinger, Thali, 2015). This last issue is mostly important in mass disaster fatalities, when scans can be directed for the identification of the victims in areas where they come from (Bollinger and Thali, 2015). The possibility to store the images proves its utility both in cases when there is a need to

reexamine after the burial or cremation of the corpse (Badam *et al.*, 2017; Bollinger, Thali, 2015), and in living victims, after the healing of the injuries (Bollinger, Thali, 2015). For the victims who were subject of various types of injuries, virtopsy helps to establish the trajectory of the projectile, to detect bone fragments- which in case of comminutive fracture of the skull would necessitate the reconstruction piece by piece (Bollinger, Thali, 2015) or projectile fragments, as well as to identify the fracture pattern or occult fractures, objectives which are difficult to accomplish by the traditional autopsy. On the other hand, in case of fragmentation or retention of the bullets, traditional autopsy is irreplaceable for their recovery (National Research Council, 2009; Ioan *et al.*, 2012), given the known importance of the projectile examination for the identification of the offender. Virtopsy is also more useful than traditional autopsy for the assessment of brain injuries when the putrefaction process began, as it preserves its anatomical features (Bollinger, Thali, 2015).

In addition to traditional autopsy, virtopsy allows an easy assessment of some regions located in areas which are difficult to evaluate, such as spinal column (Badam *et al.*, 2017), especially cranial-spinal junction, detection, distribution and quantification of gaseous embolism- which often puts in difficulty the forensic pathologist (Bollinger, Thali, 2015; National Research Council, 2009).

Virtobot is a multifunctional robotic system, originated in the initial project, which helps to avoid the interpersonal inaccuracy that may intervene when markers are applied on the body surface. Hence, the results of the virtopsy become more standardized and more accurate (Badam *et al.*, 2017). More, when the samples are taken using Virtobot, the contamination of the personnel is avoided, as they do not need to handle the samples taken from the bodies with infectious diseases (Bollinger, Thali, 2015).

DNA fingerprint- the “optimal method in identification”

Discovering the genetic fingerprinting technique, the innovation that changed the perspectives in the science, owes to Sir Alec Jeffreys, from the University of Leicester, UK, who in 1984 “found extraordinarily variable and heritable patterns from repetitive DNA analysed with multilocus probes” (Roewer, 2013). The first use of that technique was outside forensic field, but in a very short period of time researchers discovered how to use it, so as in 1987 it was applied for the identification of the offender in a double rape and homicide case, further being extended to the civil cases, having in this

way an important social and political contribution alike (Roewer, 2013). This technique implies the comparison of DNA from two samples: a sample found at the crime scene and a sample collected from the suspect, in this way being possible to establish the match or, on the contrary, the exclusion (Roewer, 2013) as well as to connect an individual to the crime scene (Zieger, Utz, 2015). In cases where investigators obtain samples solely from the crime scene- as in cases where the offender ran away, DNA profile may be compared with DNA profiles stored in databases (Cho, Sankar, 2004).

DNA is present in almost all the cells of our body, it is resistant to putrefaction, easy to store and preserve for long periods of time. DNA analysis uses only small amounts of biological sample and over the years became cost-effective (Taborda, Arboleda-Florez, 1999).

Forensic DNA profiling technologies went through a remarkable progression since their very beginning in 1980s until the contemporary era, being an undeniable help in the identification of the victims affected by natural disasters or by wars and in solving criminal cases by the identification of the offenders (Roewer, 2013; Williams, Wienroth 2017), the exoneration of the falsely accused (Roewer, 2013) or in the security field (Williams, Wienroth 2017). The evolution went through improvements in each of the DNA processing stages, from collection, to extraction and analysis. One of the most important progress in this field refers to the “next generation sequencing” or “massively parallel sequencing” technologies, which make available through genetic analyses (Williams, Wienroth, 2017).

Forensic DNA profiling and databasing contributed during the years to an improvement in the investigation procedures (Williams, Wienroth, 2017) and, implicitly, to a higher number of solved cases.

CODIS- Combined DNA Index System is a database in which DNA profiles are generated according to the STR (short tandem repeat) analysis. It has two sections: Convicted Offender Index which contains DNA collected from the convicted persons and Forensic Index which includes DNA profiles collected from the crime scene. In Romania the investigators use CODIS, the National System of Genetic Judiciary Data at the Institute of Criminalistics which is connected with databases from Austria, Netherlands, Slovenia, Spain, France and Germany (https://www.ornl.gov/sci/techresources/Human_Genome/elsi/forensics.shtml, <https://www.fbi.gov/services/laboratory/biometric-analysis/codis>).

Enhancement of the original technology over the time was made by the transition from Southern blot to polymerase chain reaction- PCR, from

radioactive to fluorescent labels, from slab gels to capillary electrophoresis. Together with these changes the sensitivity increased, operation became easier, and statistical interpretation of data refined. Currently, the method is a common standard in forensic laboratories over the world (Roewer, 2013).

A particular significance have lineage markers, such as: Y chromosome, useful in cases when DNA of the female victim exceeds the amount of DNA of the male offender and mitochondrial DNA, useful when the nuclear DNA in the sample is in small amount, as in bone fragments from skeletonized bodies or hair without root (Roewer, 2013). Progress in this field challenged the researchers to be more and more interested to find as much information as possible from DNA molecule, going up to attempt the identification of the nature of the tissue or the time of the day the person left the evidence (Zieger, Utz, 2015).

Challenges raised by the use of the new technologies in forensic medicine

The application of the new technologies in legal medicine aims, on one hand, to support the judiciary by providing evidence of great credibility and, on the other hand, to reduce the number of wrongful convictions and to reduce the risk that the real criminals continue to commit crimes (National Research Council, 2009).

However, the new technologies that are increasingly being used in forensic medicine also bring new challenges for this field. Forensic evidence has a degree of certainty and credibility unprecedented. However, they are no less likely to be mistaken. Their features, such as technical complexity, the use of databases, the ability to connect databases to one another, can exacerbate the conditions that caused mistakes in classical techniques. In addition, new technologies in forensic medicine have the ability to prove by themselves a suspect's guilt. Under these circumstances it is essential to carefully check and monitor their correctness (Murphy, 2007).

New technologies bring with them financial challenges as they require significant financial investments in sophisticated equipment as well as the training of experts with the technical expertise needed to use them (Murphy, 2007). More, the new technologies are still confronting with technical difficulties and are subject to further improvements and adjustments.

On the other hand, the high degree of sophistication that characterizes new technologies creates problems in understanding their

outcomes and limitations by people outside the field, such as those in the field of justice - the main beneficiaries of evidence provided by forensic evidences. Under these circumstances, close collaboration between forensic and legal professionals is essential so that forensic evidence is properly used and judicial procedures can be properly adjusted (Murphy, 2007, National Research Council, 2009).

Challenges raised by the application of virtopsy

Currently, virtopsy is not yet accepted to fully replace classic autopsy, the latter still providing different and ancillary data as opposed to virtopsy. This is the case with the use of senses such as touch, which enables to feel the texture (Badam *et al.*, 2017; Bollinger, Thali, 2015), which is many times imperative for diagnosis. In advanced stages of putrefaction or in substantial dilacerations, the integrity of the vascular bed is lost, and thus angiography became useless. Likewise, in some cases of natural death, virtopsy is not able to establish the cause of death. Another aspect to consider is the increased cost for this technology (Bollinger, Thali, 2015).

In 2012 was founded The International Society of Forensic Radiology and Imaging which aims to allow a permanent exchange of the research results among its members and to develop quality standards for the techniques they use (www.isfri.org). In 2012, was created a Technical Working Group Postmortem Angiography Methods in order to promote the best practice in this field. Consisting of seven European Forensic Institutes, it develops safe and standardized methods and guidelines for the performance and assessment of postmortem angiographic examinations (<http://www.twgpam.org/index.php/members>)

Challenges raised by the use of new technologies in forensic toxicology

Apart from the multiple advantages they bring, the new technologies in forensic toxicology are still characterized by some limits, mainly technical difficulties, such as: some devices need very high pressures, which may not be accomplished in practice (Smith *et al.*, 2007); ion supression is problematic for some matrices and applications; the need for a ultra-low vacuum; the absence of common spectral libraries as the assembling of spectral libraries is just at the beginning. Together with these are the increased costs connected to the acquisition of these technologies and their use in the current forensic practice (Smith *et al.*, 2007; Ioan *et al.*, 2015).

Challenges posed by the use of DNA technology

The most important ethical and technical challenges in forensic medicine and justice are brought about by the application of DNA technology (Taborda, Arboleda-Florez, 1999).

The main challenge raised by the application of the DNA technology in forensics is represented by the impact of its results on the presumption of innocence and on the suspect's right to a fair trial. In this context, the issue of the suspect's right to refuse DNA analysis in the virtue of his right of not to incriminate has arisen. Another issue is the obligation of those who perform the analysis to apply fair statistical calculations and to relate to the probability of a random match (Taborda, Arboleda-Florez, 1999, Saks, Koehler, 2005).

Despite the high certainty results generated by the DNA analysis, they can still be threatened by a variety of errors produced by faulty handling (e.g. faulty labeling, loss of evidence) or misinterpretation of data (National Research Council, 2009). In this regard, Supreme Court in Canada issued in a case the decision of inadmissibility of the DNA evidence because of poor scientific manipulating of the samples (Makin, 1997). The risk of error can be significantly diminished by using standardized procedures by qualified personnel (National Research Council, 2009).

The main ethical challenge raised by the use of the DNA analysis in forensic medicine concerns confidentiality, with a special referral to the stored data and the time frame they may be kept after a suspect's conviction. With the compilation of the data that are stored in biobanks, the confidentiality is exposed to a high risk, and sometimes a person may be found guilty on the base of DNA evidence before he/she had the chance to prove his/her innocence (Taborda, Arboleda-Florez, 1999).

There are authors who oppose DNA harvesting from the suspects and convicted people due to the danger of violation of their privacy and other rights of the innocents as well as the fear that arrests could be abusive only to get as many samples of DNA as possible.

Regarding the individuals who may be the source to collect DNA for databases, there is still a debate. In UK, for instance, they collect samples from all the suspects. This may be a problem as the ethnical minorities are over numbering in the population of the arrestee and in databases and there may be the risk for an ethnic bias in the legal system.

The supporters of the collecting DNA samples from all those arrested consider that major crimes are often committed by people who have committed other crimes, which is why the routine DNA sampling from

all those arrested would allow easier identification if their DNA already exists in the database. Also, many innocent people are often incarcerated for crimes they have not committed, but the existence of their DNA in databases would prevent this.

On the other hand, those who oppose the routine harvesting and biobanking of DNA samples from all those arrested are questioning the ethical and legal issues raised by DNA retention of those who are declared innocent at the end of the legal investigation. Thus, if the DNA profile of an innocent person is in the database, it may be identified as completely or partially matched to the DNA at the crime scene. This is possible if that person was previously at the crime scene or if he/she has a profile similar to the real killer.

Risk of stigmatization/discrimination is also an important issue associated to DNA biobanking. This is the case when the information gained from DNA analysis and stored in the database may presume that the individual has the potential to become an alcoholic, criminal or develop a violent behaviour. Outside the forensic field, this kind of information- along with predisposition to a particular disease, or sexual orientation, that DNA analysis may also reveal- may lead to genetic discrimination on the part of state, employers, insurers, school etc. (https://www.ornl.gov/sci/techresources/Human_Genome/elsi/forensics.shtml).

Conclusions

Forensic medicine went through an important progress in the last decades following the application of new technologies, be them especially designed for this field or adapted from other fields. We may say that all the activities and analysis methods in forensic medicine met a propitious evolution after implementing various new technologies.

On the one hand, the new technologies had a significant influence for the manner in which the dead bodies and the living victims are assessed, and on the other hand they created the possibility to perform trustful laboratory investigations, a genuine support in drawing appropriate conclusions in the forensic investigations.

Given the high degree of sophistication showed by the new technologies the forensic experts have the duty to properly inform the professionals outside the forensic field- especially those in the legal system- on their results and limitation.

Despite the obvious advantages brought by the application of the new technologies in forensic medicine, they also raise new challenges and in the same time increase the responsibility of the professionals in this field for the fairness of the evidence provided to the legal system so that the new technologies applied in forensic medicine promote the primary objective of this field, namely to protect society by providing credible and relevant evidence.

References

- Badam, R.K., Sownetha, T., Babu, D.B.G., Waghray, S., Reddy, L., Garlapati, K., Chavva, S. (2017). Virtopsy: touch-free autopsy. *J Forensic Dent Sci.*, 9(1), 42.
- Benghiac, A.G., Budacu, C., Moscalu, M., Ioan, B.G., Moldovanu, A., Haba, D. (2017). CBCT assessment of the frontal sinus volume and anatomical variations for sex determination. *Romanian Journal of Legal Medicine*, 25(2), 174-179.
- Bollinger, S.A., Thali, M.J. (2015). Imaging and virtual autopsy: looking back and forward. *Philos Trans R Soc Lond B Biol Sci.*, 370(1674). pii: 20140253.
- Cho M.K., Sankar P. (2004). Forensic genetics and ethical, legal and social implications beyond the clinic. *Nature Genetics*, 36(11Suppl), S8-12
- Gorun, G.S, Dermengiu, D., Curcă, G.C., Hostiuc, S., Ioan, B., Luță, V. (2010). Toxicological drivers issues in „legal highs” use. *Romanian Journal of Legal Medicine*, XVIII(4), 271-279.
- Ioan, B.G., Jitaru, V., Damian, R., Damian, S. I. (2015). Study on the relationship between the concentration of ethanol in the blood, urine and the vitreous humour. *Romanian Journal of Legal Medicine*, 23(3), 211-216.
- Ioan, B., Alexa, T., Alexa, I. (2012). Do we still need the autopsy? Clinical diagnosis versus autopsy diagnosis. *Romanian Journal of Legal Medicine*, 20(4), 307-312.
- Kloosterman, A., Mapes, A., Geradts, Z., van Eijk, E., Koper, C., van den Berg, J., Verheij, S., van der Steen, M., van Asten, A. (2015). The interface between forensic science and technology: how technology could cause a paradigm and shift the role of forensic institutes in the criminal justice system. *Philos Trans R Soc Lond B Biol Sci*, 370(1674). pii: 20140264
- Makin, K. (1997). DNA evidence-gathering curbed: top court slams RCMP. *The Globe and Mail*, p. A7.
- Murphy E. (2007). The New Forensics: Criminal Justice, False Certainty, and the Second Generation of Scientific Evidence. *California Law Review*, 95(3), 721-797.
- National Research Council. (2009). *Strengthening Forensic Science in the United States: A Path Forward*. Washington, DC: The National Academies Press.
- Petre-Ciudin, V., Hanganu, B., Velnic, A.A., Ioan, B.G. (2017). Epidemiology of spinal trauma in north-eastern part of Romania. *Forensic Sci Int.*, 277(Suppl. 1), 220-221.

- Roewer, L. (2013). DNA fingerprinting in forensics: past, present, future. *Investig Genet*, 18(4), 22
- Saks M.J., Koehler J.J. (2005). The coming paradigm shift in forensic identification science. *Science*, 309, 892-895.
- Scripcaru, C., Agrosoaie, I., Ceavdari, N., & Manoilescu, I. (2007). Forensic stomatological identification of a murderer. *Rom J Leg Med.*, 15(1), 45-49.
- Smith, M.L., Vorce, S.P., Holler, J.M., Shimomura, E., Magluilo, J., Jacobs, A.J., Huestis, M.A. (2007). Modern instrumental methods in Forensic Toxicology. *J Anal Toxicol*, 31(5), 237-9A.
- Taborda, J.G.V., Arboleda-Florez, J. (2017). Forensic Medicine in the next century: some ethical challenges. *Int J Offender Ther Comp Criminol*, 199, 43(2), 188-201
- Thali, M.J., Yen, K., Schweitzer, W., Vock, P., Boesch, C., Ozboda, C., Schroth, G., Ith, M., Sonnenschein, M., Doernhoefer, T., Scheurer, E., Plattner, T., Dirnhofner, R. (2003). Virtopsy, a new imaging horizon in Forensic Pathology: virtual autopsy by postmortem multislice Computed Tomography (MSCT) and Magnetic Resonance Imaging (MRI) – a feasibility study. *J Forensic Sci.*, 48(2), 386-403.
- Velnic, A.A., Hanganu, B., Petre-Ciudin, V., Ioan, B.G. (2017). Clinical diagnosis versus autopsy diagnosis in head trauma. *Forensic Sci Int.*, 277(Suppl. 1), 209.
- Williams, R., Wienroth, M. (2017). Social and ethical aspects of Forensic Genetics: a critical review. *Forensic Sci Rev.*, 29(2), 145-169.
- Zieger M., Utz S. (2015). About DNA databasing and investigative genetic analysis of externally visible characteristics: A public survey. *Forensic Sci Int Genet*, 17, 163-172
- www.omicsonline.org/pathology/forensic-pathology-innovations.php
- www.isfri.org
- <http://www.twgpam.org/index.php/members>
- <https://www.fbi.gov/services/laboratory/biometric-analysis/codis>
- https://www.ornl.gov/sci/techresources/Human_Genome/elsi/forensics.shtml