PERSPECTIVE ARTICLE

Metaversopsy - A Perspective

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'Metaverse' is a big buzz word in the world of technological advancement nowadays. Interestingly, there are lot many definitions for this term from being just a hypothetical iteration of internet in science fiction to being an absolutely true virtually interacting medium. However, one of the most acceptable definitions from my point of view would be, "A massively scaled and interoperable network of real time rendered 3D virtual worlds that can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, communications, and payments [1]."

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The next important question that pops up in one's mind is, *'why should a forensic pathologist be aware of the advances in the field of computer science/tech'?* The straightforward answer would be whether we like it or not, technology is always on the go to disrupt every single branch of medicine either purposefully or forcefully. Moreover, it is not nonsensical to accuse molecular biologists and computer science geeks about their extremely heightened enthusiasm in encroaching on to every other domain in the universe to just ensure their relevance. On top of that, if we look at the current climate of medical research in the aftermath of COVID 19 pandemic, there is an additional renewed interest in molecular medicine, imageology and digital health.

Although metaverse can purportedly revitalize health sector to a great extent, the most simplified understanding of what metaverse does when we look at it from a broader prospect is-

- Primarily, connected health and Internet of Medical Things (IoMT) in their Zenith. It is an increased and immersive telepresence of health care providers generating an easy access to outpatient services coupled with advent of extremely reliable wearables to acquire vital data remotely. Indeed, to make this a reality there needs to be a convergence of artificial intelligence, virtual reality (VR), extended reality (XR) and augmented reality (AR) in synchrony with the blockchain technology that ensures data protection.

- Secondly, the digital twinning. It is the creation of a virtual model of the real-life counterpart in the metaverse for research purpose. Lucidly said, it is bioinformatics performing at its Everest peak! There are several such dry lab techniques in scientific research. E.g., Quantitative Structure Activity Relationships (QSAR) mathematical models to predict measures of toxicity using molecular descriptors in toxicology. This is also referred to as something called augmented regulatory science. Several such approaches of research are a part of dry lab in drug design and development from a long time. We can assume that this digital twinning is more or less the same in a magnificent magnitude like the science of precision medicine.

It has been claimed by several researchers that a Metaverse of medical Technology and Artificial Intelligence (MeTAI) ecosystem can facilitate research and performance of AI based medical practice especially in the field of radiology and its allied specialities [2]

I shall not dole out deep in to the explainability of AI and deep learning paradigms being employed for usage in metaverse. Neither I wish to bring in the bioethics or legal issues entangled with the use of metaverse in health at this juncture. These legal and ethical considerations all together constitute a recalcitrant challenge better kept open for the reader to comprehend.

Of late, we as practicing crime pathologists can't deny the presence of a lot of published data in the field of digital pathology in general and virtual autopsy (virtopsy) in particular, despite the hard fact that these things can only complement and never substitute the traditional autopsy. As we are aware, the virtopsy model encompasses the use of certain technologies like 3D body surface imaging methods, multidetector and multi-slice computed tomography (CT), magnetic resonance imaging (MRI), data merging of surface and radiological data, high-resolution micro-CT and micro-MRI (MR microscopy), magnetic resonance spectroscopy (time-of-death determinations), image-guided percutaneous biopsy, post-mortem angiography and synthetic body model development [3]

Virtopsy came into existence during the first decade of the 21st century and since then has been used across the globe in several jurisdictions. It has also been successfully applied to solve many medico-legal questions till date. Prof. Dr. Michael Thali and his team at the institute of forensic medicine, university of Zurich, Switzerland is one of the most active research groups in this arena.

Metaversopsy can be defined as a technologically aided autopsy procedure that converges multiple existing human imaging modalities, robotics and artificial intelligence to enhance the scientific perceptibility of the forensic pathologist on real time basis. There is an unusually high degree of interoperability of technologies reduced in space and time, thereby turning it out to be a perfect *virobot* master slave system and even more than that!

It isn't all new approach, but when we develop an algorithmic approach with due standardisation and validation like it was done in the case of virtopsy, Metaversopsy can be an altogether next generation tool in the arsenal for forensic autopsy. If we consider that the average time to conduct a traditional autopsy is somewhere between 3-6 hours, the existing virtopsy method can aid us in reducing it to 1-2 hours. If Metaversopsy comes into existence one can achieve impeccable speed of performing an autopsy in span of minutes.

If we dissect the idea further, Metaversopsy is a no scalpel/ non-destructive or minimally invasive imageology and 3D reconstruction-based autopsy procedure like virtopsy except for the fact that there are elements of machine intelligence/learning, robotics and convergence of image/ intervention technologies being used in real time. The data which gets processed through machine intelligence/learning and deep learning networks may be presented on a virtual interactive interface to the pathologist. The pathologist also may be able to delve deeper into the levels of body with the virtual tools available for him with his choicest views and magnifications using his VR/AR/XR headset and command the robotic system for any interventions on the corpse. Apart from this, the technology can also apparently be upgraded further for providing suggestions as to causative factors of trauma and differential diagnosis in connection with morbid anatomy findings in the corpses (Figures 1 and 2).

The concept of corpse twinning, i.e., creating a virtual counterpart of the deceased will give us a meaningful scope to investigate the possible mechanisms of infliction of violence in majority of the cases. This is absolutely an improvement of what is being practiced today because we aren't using the exact replica of a person/milieu in simulations as of now. Sometimes, *phantoms* can be printed using 3D printing technologies which may eventually replace dummies in simulation experiments. Personally, I wish for this kind of a virtual media solution to make medical illustration easier in the courts of law for people from different backgrounds.

Corpse twinning is like the digital twin of the patient for the purpose of risk assessment and precision therapeutics. This approach will augment existing simulation methods in investigating cases of ballistic injuries, injuries due to missiles, fire accidents, fall from height, bomb blasts and mass disasters. Nevertheless, developing case specific algorithms and standardization of corpse twinning demands a lot of dry lab work before it can be started on a real time basis. But, if Chat GPT can happen, corpse twinning will also be a reality for sure.

The seamless virtual connectivity expected from metaverse helps us to work in teams from across the globe in real time. A trans-continental autopsy wouldn't be that far into the future with metaverse in the horizon. Obviously, when more human brains are at work, we have better results. I always believe that the two most important byproducts of technology making inroads in forensic pathology is democratization of knowledge and increased transparency in the actions of so-much hyped forensic expert's work!

Illustration - Firearm injuries case:

When the corpse passes through the Metaversopsy suite, a corpse twin is created in the virtual world by integrating multimodal surface and radiological imaging along with 3D Photogrammetry. AI based technologies depict the track of the wound, detail of the distorted projectile, its virtually reengineered pure form and creates a simulation of launch of the projectile and subsequently furnishes type, range and direction of fire in real time basis. Machine learning and deep learning algorithms help in this process using neural networking model. There is always a scope for error and pathologist need not always subscribe to the suggestions of the bot-metaverse system. She can use her brains to negate the *Metaversopsy* suggestions and this will subsequently work through deep learning neural networks for the AI becoming smarter in future. This data can also be shared among professionals for case discussion and presented to the ballistic expert for furthering his study in confirming the class and individual characteristics of the weapon. The Robot system aids the pathologist in image guided tissue/sample collection for ancillary investigations or further analysis (Figs. 1 and 2).
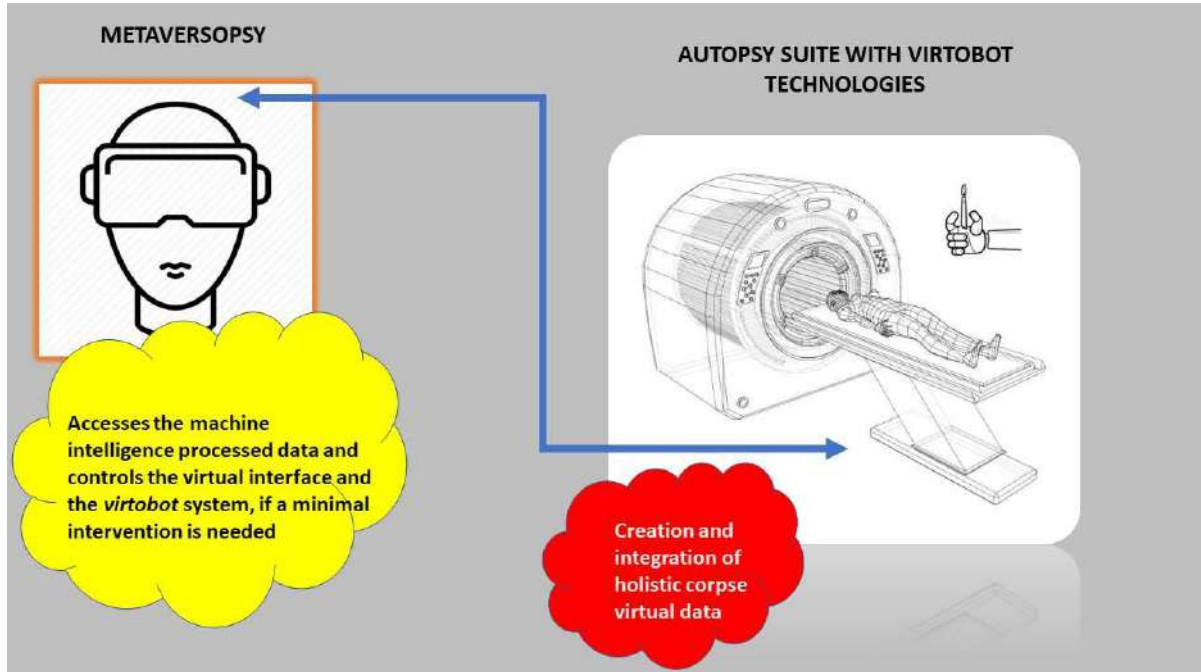
Figure 1: The autopsy surgeon works on a virtual interface integrated with a robotic system to carry-out additional interventions like obtaining samples for ancillary investigations.
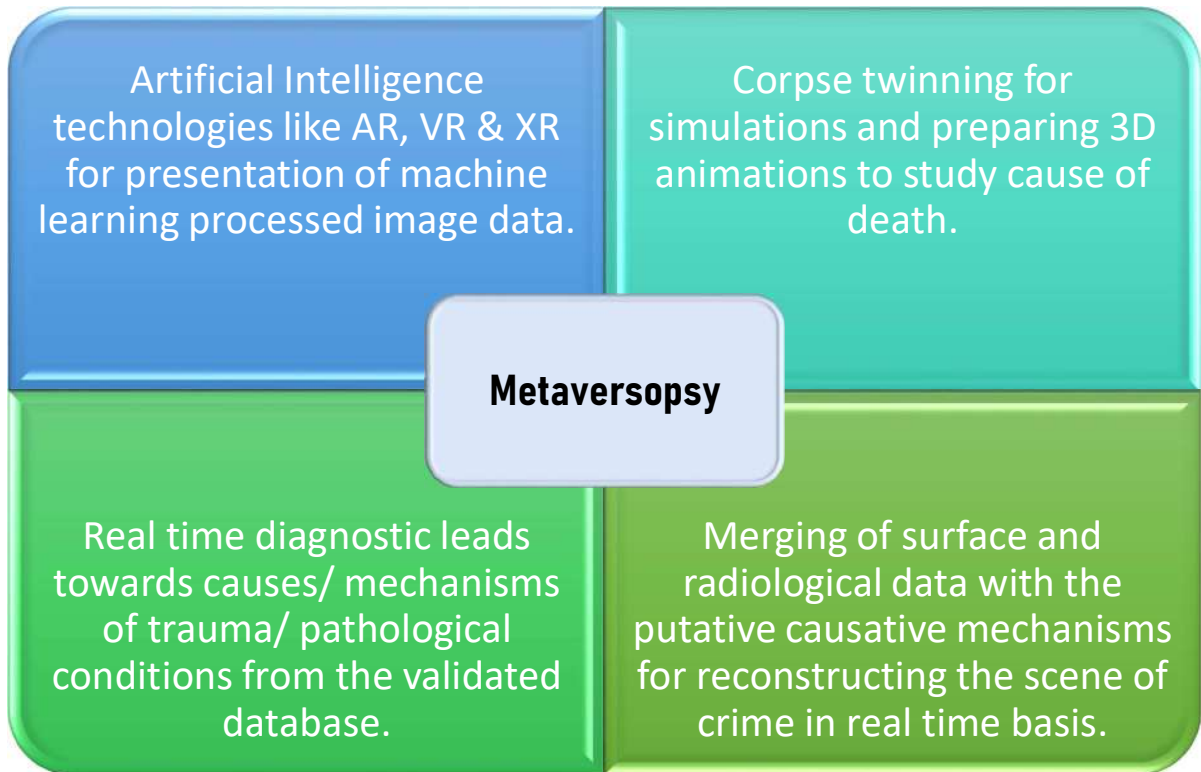

Figure 2: Convergence of Artificial Intelligence, Robotics, and Medical Imaging Technologies in Forensic Pathology – Metaversopsy.

Collection, storage, processing, further processing and transfer of sensitive personal data requires a strict compliance of General Data Protection Regulation (GDPR) and its respective recitals. The cardinal principles of data privacy and security are enshrined in the article 5.1-2 of the GDPR. These include lawfulness, fairness & transparency; purpose limitation; data minimisation; accuracy; storage limitation; integrity & confidentiality; and accountability [4]. Needless to say, storage and reproduction of the data of the deceased person for scientific reporting and archiving necessitates a tamper-proof privacy framework. A strict Data Impact Assessment (DIA) is essential in this scenario to anticipate any future data privacy issues before implementing the programme. A complete and comprehensive regulatory mechanism for data protection in compliance with GDPR is quintessential. Nevertheless, handling and transfer of such extremely sensitive data is a huge matter of privacy concern in medico-legal issues especially in cases of violent sexual crime on women and children.

The high volume of processed as well as raw data that is generated during *Metaversopsy* requires a proper anonymisation before being employed for educational and research purposes. The legal issue of ownership of data currency of the deceased person and all matters incidental thereto needs to be thoroughly thought out before venturing further. The rights of the deceased 'data subject' is altogether a novel concept in privacy law which requires a detailed study. Hopefully, the blockchain technology addresses some of these challenges. Blockchain technology can ensure privacy through the use of techniques such as Zero-Knowledge proofs and homomorphic encryption. Zero-knowledge proofs allow for the verification of information without revealing the actual data, while homomorphic encryption allows for computations to be performed without the need to decrypt it first [5].

If the Metaversopsy clears the simple test of science, it would be just a matter of time to rope in all stakeholders of criminal justice system into the confidence bracket of technology-based solutions in autopsy practice.

Nonetheless, it's a long way to go wherein we are supposed to go for hybrid practice for at least a few years to generate more data to pass the standardisation test.

There are several people who buy water for the idea of metaverse, and we also do have equally good number of critics who are hyper-sceptical about the feasibility of such a large-scale financial project. These references can be accessed for instance [6,7].

Unfortunately, most of the research in medicine is not being aimed at the unmet needs of patients or propositions made by clinicians. Although this is a personal opinion, I feel like there are three major industries subterraneanly dictating medical research. They are firstly the *IT industry*, secondly the *central dogma group of molecular biologists* and finally the *imageology physicists*. All the three groups share a commonality of delusion of *pan-panacea!*

The only perfect rationale for image-tech based solutions in autopsy practice from my perspective is, we can use it in situations like COVID 19 pandemic. It is no exaggeration that the entire modern medicine took its birth in autopsy theatres where corpses were dissected, and disease pathology was studied. Autopsy pathology still remains the gold standard in understanding emerging and re-emerging novel pathological basis of disease. Hence, where traditional autopsy is risky and takes huge time, technologies like the Metaversopsy on a grand scale can provide some quick and reliable solutions in times of crisis. The quantum leap in Metaversopsy technology will take its own time to crystallize but will definitely get established in practice.

In our country, the virtopsy project was launched at the AIIMS, Delhi recently with support from ICMR. The research team under the stewardship of Prof. Dr. Adarsh Kumar opined that although this concept emerged a couple of decades back, it did not pick up quick acceptance in the forensic field comparted to techniques like the DNA analysis which have become so ubiquitous. It is also an undeniable fact that the costs involved in software, hardware of image-based methods will delay the implementation in our country [8]. It is also worth to mention that AI based methods were

also employed in India to estimate time since death which is one of the primary objectives of a medico legal autopsy [9].

The National Convention on Medicine and Law 2018 organised by Institute of Medicine and Law, Mumbai, compiled several issues pertaining to the need and legality of virtopsy in India. It was also mentioned during the conclave that cost won't be a hindrance in the long run because we can make our tailor-made software with the help the giant IT ecosystem in the county. Moreover, in a country like India, the economies of scale will help in cost cutting. The same principles augur well for *Metaversopsy*. There is nothing in Indian law that bars imageology in autopsy practice. The evidentiary value of such reports would fall under the ambit of Sec 3(2), Sec 45 and Sec 62 of Indian Evidence Act (IEA). It is also important to mention that all the relevant provisions of Information Technology Act 2000 Shall apply to these image-based methods because high fidelity cybersecurity is essential when virtopsy is being extended to the metaverse. On the other hand, this shall also open vistas of tampering of digital evidence and crimes related thereto which is beyond the scope of present discussion [10]. One also needs to bear in mind that, although image-based technologies can increase objectivity in arguments they are also limited by certain biases and element of subjectivity in medico-legal practice.

The major risk of excessively relying on technology is sometimes it can land us in more problems than it was intended to solve. The principles laid down by WHO in the vision document on ethics and governance of AI in health and the recommendations of UNESCO on ethics of artificial intelligence are worth reviewing to open the debate of risks and benefits in using metaverse to solve medico-legal issues [11,12].

The ultimate advantage for the forensic pathologist with advancements of this sort would be saving a lot of time in framing opinions, especially when there is a huge workload in a high-volume centre or when there is an acute increase of workload due to mass disasters. There is no doubt adoption of this technology increases presentability and probative value of evidence in the courts of law. The purported benefits for the other stakeholders like the relatives of the deceased would be a minimally invasive autopsy and more comprehensive understanding about cause of death. There is an obvious increased ease of solving crime for the different agencies which are part of criminal justice system.

It would be a smack of myopia if I don't put a word on the feasibility of the project. The hardware, software involved in the project along with the wearables like immersive VR/AR/XR headsets are hugely expensive at this point of time. The training of forensic pathologists and other ancillary staff towards adopting such technology and managing the huge dataset takes considerable amount of time. The cost effectiveness and risk benefit analysis of this project needs to be carried out in a more scientific way by future researchers.

In conclusion, with my understanding on the subject, I can assure that we aren't discussing science fiction, and everything makes sense in view of the steep pacing technology research blended with increased paradoxical curiosity to find a solution for everything in AI. It is good sometimes! Metaversopsy can also become a VR game in Zuckerberg's Metaverse! Who knows!

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