Peer Reviewed
Received 1 February 2018
Received in revised form 6 March 2018
Accepted 7 April 2018
Available online 7 May 2018

Forensic Science Seminar
ISSN 2157-118X
Volume 8 Number 1
3 April 2018

Application Status and Intelligent Trend of Digital Forensic Pathology in Identification Practice

GUO Qi [a], **XUE Haibin** [b, *]

a. Public Security Bureau of Bishan District in Chongqing, Chongqing, 400000, China.
b. Liangjiang New Area Branch of Chongqing Public Security Bureau, Chongqing, 400000, China.
*CORRESPONDING AUTHOR. E-mail: 33220025@qq.com; Tel: +86-13983045601.

ABSTRACT The traditional forensic identification methods rely mainly on the naked eye observation and empirical judgment of the appraisers in the process of autopsy and histopathological examination. The impartiality and scientific nature of the identification opinions thus formed are often questioned, often causing the parties to suffer due to evidence. Or conflict with the case handling party. Forensic pathology and medical imaging, computer simulation and other multidisciplinary integration formed a series of new digital technologies, which are revolutionizing forensic identification technology.

KEY WORDS Forensic pathology, Virtual anatomy, Multi-rigid body simulation, Finite element analysis, FEA, Forensic science

1. INTRODUCTION

Forensic autopsy is a fundamental method and gold standard for recognizing clear causes of death. The traditional forensic identification methods rely mainly on the naked eye observation and empirical judgment of the appraisers in the process of autopsy and histopathological examination. The impartiality and scientific nature of the identification opinions thus formed are often questioned, often causing the parties to suffer due to evidence. Or conflict with the case handling party. Some of the lesions may not be able to obtain enough powerful information through autopsy, and the traditional autopsy is a destructive examination. For centuries, it has been resisted and opposed by the families of the deceased, especially by some religious cultural traditions [1].

Forensic pathology and medical imaging, computer simulation and other multidisciplinary integration formed a series of new digital technologies, which are revolutionizing forensic identification technology.

At present, virtual anatomy, multi rigid body simulation and finite element analysis are the most mature technologies.

2. VIRTUAL ANATOMY

With the development of medical imaging techniques such as CT and MRI, it provides a non-invasive/minimal invasive cadaveric examination method for forensic medical examination—the forensic virtual anatomy technique that can clearly observe the cadaver organs, bone lesions and damage, and can save the parts of the body image data, is conducive to late re-examination and consultation, the detection of forensic injury and the cause of death has a great value.

In the 1990s, Dr. Thali *et al.* [2] of the Institute of Forensic Medicine at the University of Bern, Switzerland, first proposed the concept of virtual anatomy and formed a theoretical system. Current virtual anatomy techniques include optical three-dimensional surface scanning, 3D photography, CT scans, and MRI scans. They make full use of the advantages of new technologies and multi-technology integration to address causes of death, forensic pathology, life response, injury reconstruction, such as forensic focus. Many countries in Switzerland, the United States, Japan, the United Kingdom, and Australia [2-5] have achieved certain research results in terms of damage detection, injury model estimation, and cause of death identification.

3. MULTI-RIGID BODY SIMULATION

With the development of economy, the increase in the types and number of vehicles, the incidence of traffic accidents and the number of dead and injured have also shown an upward trend, which has become an important factor affecting social development and people's lives. The identification of traffic accidents has also gradually risen to a forensic pathology, the focus identification project. In recent years, with the development of computer hardware and numerical simulation technology, it has become technically possible to reconstruct traffic accidents through digital reconstruction methods. The digital photogrammetry technology and multi-rigid body dynamics simulation technology can reconstruct the accident scene and digitally simulate, simulate and visualize the collision and injury process in the accident, thus assisting in the development of the forensic identification of traffic injuries, and the accuracy, objectivity of accident identification, and impartiality and scientific treatment of accident liability.

Since the 1970s, research institutes in the United States, Europe, Japan, and Australia have used multi-rigid body dynamics methods to perform vehicle crash tests and impact tests of occupant protection devices, which have caused structural deformation and crashworthiness of vehicles in collision accidents. As well as issues such as safety, a simulation analysis was carried out to reveal the injury mechanism of the vehicle's personnel, formulate damage assessment standards, and propose improvements to the vehicle design. Since the beginning of the 21st century, European and American research institutions have begun to use multi-rigid pedestrians and vehicle models to reconstruct real road traffic accidents, simulate car-pedestrian collisions, reproduce the process of injury caused by traffic accidents, and determine the posture of pedestrians, the collision speed and the braking state of vehicles, etc. And analyze the impact of factors such as vehicle type, body shape, initial posture, and vehicle braking status on pedestrian distance, location and human injury after collision. [6-9]

The research on simulation and simulation of multi-rigid traffic accidents in China started relatively late. The digital reconstruction of car-pedestrian crashes was mainly carried out after 2002. Tsinghua University, Jilin University, Hunan University, Third Military Medical University and other research institutes have independently constructed or apply commercial models to reproduce the real-world case of car-pedestrian collision accidents. The research content includes the relationship between vehicle speed and body throw distance. The characteristics of different vehicle speeds and different vehicle models causing damage to the outside of the car are discussed, including the possibility of protection from outside the vehicle. [10-13]

4. FINITE ELEMENT ANALYSIS (FEA)

The analysis of human forensic pathology by traditional forensic pathology mainly depends on naked eye observation, autopsy, light microscope observation and empirical judgment. The subjective arbitrariness is strong, and the understanding of damage is mostly limited to damage morphology. [14]

The finite element model of the human body is composed of the decomposition and reorganization of human tissues in unit discrete and three-dimensional modeling. It can perform load simulation on specific boundary conditions, calculate the effect of external forces on human tissue, and finally obtain various Human biomechanical results. The finite element method is of great help in reconstructing and predicting the locations, forms, and degrees that may occur in human injury, improving the shortcomings of traditional forensic pathology, and providing a favorable reference for forensic identification of injury.

Since the 1970s, the finite element method has been applied to the modeling and damage biomechanics of the human head, spine, etc. The research scope has gradually expanded to the pelvis, thorax, and joints of the limbs and other structures. In addition to the skeletal system, finite element models have been constructed for cardiovascular, ocular, gastrointestinal, pulmonary, hepatic, renal, and even placental sites and lesion analyses have been performed. At present, finite element modeling and analysis methods have achieved certain results in the following biomechanical studies of common injuries, including accelerations caused by acceleration/deceleration of the head and injuries caused by rotational motion, and internal organs caused by the external force of the chest and abdomen, injury to blood vessels and damage to the thorax, spine, pelvis, and joints of the limbs and attachments caused by external violence. [14-18]

The study on the relationship between finite element modeling and human injury started relatively late in China. In recent years, there have been reports of research results in succession, mainly focusing on the fields of engineering and material mechanics, traffic injury prevention and clinical trauma research. The Southern Digital Medical University, the Third Military Medical University, and Shanghai Jiao Tong University have developed digital avatar programs for medical research, clinical treatment and teaching, and have achieved corresponding research results. The human biomechanical model research plan is used to simulate the collision between different parts of the vehicle and the human body in a traffic accident, to perform numerical response analysis and to study the injury mechanism of human injury. [19-20] In addition, based on the research needs of weapon damage protection; relevant agencies in China have also conducted relevant research on chest finite element modeling and damage analysis. [21-22]

However, there is a certain gap between the focus of the above research work and the damage morphology, damage mechanism, and biomechanical analysis of damage in forensic science research.

5. DISCUSSION

Through virtual anatomy technology, human injury can be clearly detected and the damage situation can be effectively evaluated. Through multi-body dynamics simulation technology, road traffic accident reconstruction can be effectively carried out, and the occurrence of real accidents and the damage of human injuries can be restored. Through finite element modeling and analysis techniques, the damage can be dynamically and quantitatively analyzed from the perspective of biomechanics to predict the site of injury and observe the occurrence and development of the injury. The formed electronic evidence can be displayed in the form of images and dynamic effects, clear, easy to understand, easy to understand the illegal medical personnel involved in the litigation process, and greatly enhance the quality of the identification of the case. In view of the differences in the principles, equipment, and concerns of the various digital technologies mentioned above, the joint application of multiple digital technologies to complement each other has become a research hotspot and development trend in the international forensic science field. [23]

According to relevant reports [24], the development of various new technologies in forensic pathology digitalization still has deficiencies, and each has its own advantages over traditional forensic identification. The combination of traditional forensic identification and digital technology can provide a more scientific and effective theoretical basis for forensic identification.

The preliminary results based on the concept of "virtual reality", such as autopsy multi-slice spiral computed tomography (MSCT) and magnetic resonance imaging (MRI), have been introduced and evaluated in forensic medicine [25]. Forensic pathology new molecules and innovative technologies are also in full swing [26]. While some research teams have recently begun to use artificially related technologies to conduct new research on forensic pathology, for example, to improve the quality of autopsy reports through computer proofreading procedures to identify errors [27]; to vector quantifiers to identify endometrial malignancies [28]; to establish a diagnostic decision support system through logical programming, supplemented by a computational framework based on an artificial neural network, establishing a model for assessing thrombophilic propensityshment of a diagnostic decision support system supplemented by formal agendas based on logical programming methods for knowledge representation and reasoning, supplemented by a computational framework based on artificial neural networks, and its model is quite accurate in assessing propensity to thrombogenicity. This model can properly classify patients who do present with pathology and can classify disease deletions [29]; *etc.*

6. CONCLUSION

At present, forensic pathology digitization technology is still in the development stage. Virtual anatomy, multi-rigid body simulation, finite element analysis and other technologies all have certain flaws and technical blind spots. Digital technology cannot completely replace traditional forensic identification and research methods. Combining digital technology with traditional identification methods, a new injury analysis model including expert system, data information system, and computer system was formed to ensure the forensic medicine and the rigor, objectivity, and accuracy of scientific evidence formed.

In less than a decade, big data in medicine has become a phenomenon, and many biomedical disciplines have their own papers on this topic. Outlook and debate are booming. However, real big data research is still very rare in medicine and does not meet all expectations. On the one hand, technologies that are usually proposed for big data (such as machine learning techniques) should support ambition for personalized, predictive and preventive drugs. Most of these technologies are not new, and they have been more than 50 years old for the oldest technologies. On the other hand, several issues that are closely related to the nature of big data and inherited from other scientific fields (such as artificial intelligence) are often underestimated if they are not ignored. In addition, some papers have adjusted almost identical enthusiasm for big data, and because they describe the risks, they deserve attention. [30] In this context, forensic science is still waiting for its position paper and a comprehensive overview of what big data can bring in this area. The current situation requires that definitions and actions reasonably guide the research and practice of big data. This is an opportunity for true interdisciplinary cooperation.

REFERENCE

1. Lundberg GD. Low-tech autopsies in the era of high-tech medicine: continued value for quality assurance and patient safety [J]. JAMA, 1998, 280: 1273-1274.
2. Thali MJ, Dirnhofer R, Vock P. The virtopsy approach[M]. CRC Press，2009.
3. Buck U, Christe A, Naether S, *et al*. Virtopsy -- Noninvasive Detection of occult bone lesions in postmortem MRI: Additional information for traffic accident reconstruction [J]. Int J Legal Med, 2009, 123(3): 221-226.
4. Buck U, Naether S, Braun M, *et al*. Application of 3D documentation and geometric reconstruction methods in traffic accident analysis: with high resolution surface scanning, radiological msct/mri scanning and real data based animation [J]. Forensic Sci Int, 2007, 170(1): 20-28.
5. Dirnhofer R, Jackowski C, Vock P, *et al*. VIRTOPSY: Minimally invasive, imaging -guided virtual autopsy [J]. Radiographics, 2006, 26(5): 1305-1333.
6. XU Jiong. Research and application of motor-bus collision accident reconstruction oriented to occupant injury [D].Shanghai: Shanghai Jiao Tong University, 2010. (In Chinese)
7. SHEN Jie. Research and application of vehicle-pedestrian accident reconstruction [D]. Shanghai: Shanghai Jiao Tong University, 2007. (In Chinese)
8. Untaroiu C D, Crandall J R, Takahashi Y, *et al*. Analysis of running child pedestrians impacted by a vehicle using rigid-body models and optimization techniques [J]. Safety Science, 2010, 48(2): 259-267.
9. Untaroiu C D, Meissner M U, Crandall J R, *et al*. Crash reconstruction of pedestrian accidents using optimization techniques[J]. International Journal of Impact Engineering, 2009, 36(2): 210-219.
10. BAI Zhonghao, CAO Libo, YU Zhigang. A research on the difference of frontal impact response between 50th percentile Chinese male and hybrid III 50th percentile male [J]. Automotive Engineering, 2008, (11): 993-997, 1005. (In Chinese)
11. CHEN Yong. Research on protection of child-pedestrian head injury in vehicle-pedestrian collisions [D]. Hunan: Hunan University, 2008. (In Chinese)
12. FENG Cheng-jian, WANG Fu-ping, XU Chen, *et al*. Head dynamic response based on reconstruction of vehicle-pedestrian accidents with the video [J]. Journal of Medical Biomechanics, 2013, 28(2): 164-170. (In Chinese)
13. GU Jie, XIA Yong, ZHOU Qing. Kinematics of the head in cyclist-vehicle and pedestrian-vehicle collisions [J]. J Automotive Safety and Energy, 2014, 5(2): 159-165. (In Chinese)
14. LIU Ningguo, CHEN Yijiu. The theory and practice of new digital techniques of forensic pathology [M]. Shanghai SciTechEducation Press, 2015. (In Chinese)
15. Jean R, Caroline D, Rémy W, *et al*. Finite-element models of the human head and their applications in forensic practice [J]. Int J Legal Med, 2008, (122): 359-366.
16. Raul J S, Baumgartner D, Willinger R, *et al*. Finite element modelling of human head injuries caused by a fall [J]. Int J Legal Med, 2006, 120(4): 212-218.
17. El-Rich M, Arnoux P J, Wagnac E, *et al*. Finite element investigation of the loading rate effect on the spinal load-sharing changes under

impact conditions [J]. Journal of Biomechanics, 2009, 42(9): 1252.
18. Li Z, Kindig M W, Kerrigan J R, *et al*. Rib fractures under anterior -posterior dynamic loads: experimental and finite-element study [J]. Journal of Biomechanics, 2009.
19. ZHOU Ze-min, FANG Chi-hua, HUANG Li-wei, et al. The study of pancreas three-dimensional reconstruction based on the Virtual Chinese Human-Female No 1 [J]. Chin J Surg, 2005, 43(21): 1401-1404. (In Chinese)
20. HE Pei. The development of a three-dimensional finite element model of the human brain and frontal impact simulation and analysis [D]. Tianjin: Tianjin University of Science Technology, 2006. (In Chinese)
21. LI Hongbo. Finite element modeling and simulation of human thorax protection based on behind armor blunt trauma [D]. Luoyang: Henan University of Science and Technology, 2012. (In Chinese)
22. ZHANG Zhigang. Research of human thorax FEM for analysis of explosion protection [D]. Chongqing: Third Military Medical University, 2008. (In Chinese)
23. CHEN Yi-jiu. The development and application of new digital techniques in forensic pathology [J]. Chinese Journal of Forensic Sciences, 2016, (3): 64-71. (In Chinese)
24. Giovanna Sansoni, Cristina Cattaneo, Marco Trebeschi *et al*. Scene of crime analysis by a 3-dimensional optical digitizer a useful perspective for forensic science [J]. The American Journal of Forensic Medicine and Pathology: official publication of the National Association of Medical Examiners, 2011, 32(3): 280-286.
25. Thali M J, Yen K, Schweitzer W, *et al*. 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]. Journal of forensic sciences, 2003, 48(2): 386-403.
26. Kondo T, Ishida Y, Kimura A, *et al*. New Molecular and Innovations in Forensic Pathology[M]//P5 Medicine and Justice. Springer, Cham, 2017: 126-145.
27. Cain M D, Brazelton J, Dye D W. Identifying errors in forensic autopsy reports using a novel web-based program [J]. Academic Forensic Pathology, 2016, 6(1): 103-108.
28. Pouliakis A, Margari N, Karakitsou E, *et al*. Artificial intelligence for the identification of endometrial malignancies: Application of the learning vector quantizer [J]. International Journal of Reliable and Quality E-Healthcare (IJRQEH), 2018, 7(2): 37-50.
29. Vilhena J, Vicente H, Martins M R, *et al*. An artificial intelligence approach to thrombophilia risk [J]. International Journal of Reliable and Quality E-Healthcare (IJRQEH), 2017, 6(2): 49-69.
30. Lefèvre T. Big data in forensic science and medicine [J].Journal of Forensic and Legal Medicine, 2017, In Press (Corrected Proof).

POSTSCRIPT

N/A