THE CURRENT STATE OF VIRTUAL AUTOPSY USING INTEGRATED VISUALIZATION TECHNOLOGIES

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Abstract

Relevance. Virtual autopsy is positioned as a non-invasive method of postmortal examination, which provides objectively verifiable forensic data without the need for a traditional autopsy.

The **aim** of this study was to evaluate the diagnostic value of virtual autopsy (virtopsy) as an alternative to traditional medical autopsy in patients undergoing intensive care in the anesthesiology intensive care unit (ICU).

Materials and methods: Study design: Prospective study. Multidetector computed tomography (MDCT), magnetic resonance imaging (MRI), 3D image reconstruction, and histological assessment performed under the supervision of certified specialists. Diagnostic data from virtual autopsy were compared with clinical diagnoses and the results of traditional forensic examination, which allowed us to evaluate the accuracy and completeness of the identified pathologies.

Results: Virtual autopsy confirms 88% of clinical diagnoses and identifies additional pathologies, such as hemorrhages, strokes, and pneumothorax, including changes that could be missed during a traditional autopsy. These findings demonstrate the high diagnostic efficacy of the method, its practical value for improving the accuracy of postmortem diagnostics, and expanding capabilities in forensic and clinical fields. Overall, the study demonstrates the potential of virtual autopsy as a promising non-invasive tool in modern medicine.

Conclusions: The study confirmed the feasibility of using virtual autopsy as an effective complement to and temporary replacement for traditional autopsy, contributing to the development of modern postmortem diagnostic methods and improving the quality of medical examinations in both forensic and clinical fields.

Keywords: virtual autopsy, virtopsy, forensic examination, imaging technologies, computed tomography, MRI, non-invasive autopsy.

Резюме

СОВРЕМЕННОЕ СОСТОЯНИЕ ВИРТУАЛЬНОЙ АУТОПСИИ С ИСПОЛЬЗОВАНИЕМ КОМПЛЕКСНЫХ ТЕХНОЛОГИЙ ВИЗУАЛИЗАЦИИ

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Актуальность: Виртуальная аутопсия позиционируется как неинвазивный метод постмортального исследования, обеспечивающий получение объективно верифицируемых судебно-медицинских данных без необходимости выполнения традиционного вскрытия.

Цель исследования: оценка диагностической ценности виртуальной аутопсии (виртопсии) как альтернативы традиционной медицинской аутопсии у пациентов, находящихся на интенсивной терапии в отделении анестезиологии и реанимации (ОРИТ).

Материалы и методы: Дизайн исследования: Проспективное исследование. Мультиспиральная компьютерная томография (МСКТ), магнитно-резонансная томография (МРТ), 3D-реконструкция изображений и гистологическое исследование, проведенные под наблюдением сертифицированных специалистов. Диагностические данные виртуальной аутопсии сопоставлялись с клиническими диагнозами и результатами традиционной судебно-медицинской экспертизы, что позволило оценить точность и полноту выявленных патологий.

Результаты: Виртуальная аутопсия подтверждает 88% клинических диагнозов и выявляет дополнительные патологии, такие как кровотечения, инсульты и пневмоторакс, включая изменения, которые могли быть пропущены при традиционной аутопсии. Полученные результаты демонстрируют высокую диагностическую эффективность метода, его практическую ценность для повышения точности посмертной диагностики и расширения возможностей судебно-медицинской и клинической практики. В целом, исследование демонстрирует потенциал виртуальной аутопсии как перспективного неинвазивного метода в современной медицине.

Выводы: Исследование подтвердило возможность использования виртуальной аутопсии в качестве эффективного дополнения и временной замены традиционной аутопсии, способствуя развитию современных методов посмертной диагностики и повышению качества медицинских экспертиз, как в судебно-медицинской, так и в клинической практике.

Ключевые слова: виртуальная аутопсия, виртопсия, кожно-медицинская экспертиза, технологии визуализации, компьютерная томография, МРТ, неинвазивное вскрытие.

Түйіндеме

КІРІКТІРІЛГЕН ВИЗУАЛИЗАЦИЯ ТЕХНОЛОГИЯЛАРЫН ПАЙДАЛАНҒАН ВИРТУАЛДЫ АВТОПСИЯНЫҢ ҚАЗІРГІ ЖАҒДАЙЫ.

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Өзектілігі. Виртуалды аутопсия дәстүрлі мәйітті ашусыз-ақ объективті түрде расталатын сот-медициналық деректерді алуға мүмкіндік беретін инвазивті емес постмортемдік зерттеу әдісі ретінде қарастырылады.

Зерттеудің мақсаты анестезиологиялық қарқынды терапия бөлімшесінде (ЖҚБ) қарқынды терапиядағы науқастарда дәстүрлі медициналық аутопсияға балама ретінде виртуалды аутопсияның (виртопсия) диагностикалық құндылығын бағалау болды.

Материалдар мен әдістер: Зерттеу дизайны: Перспективалық зерттеу. Сертификатталған мамандардың бақылауымен жүргізілген көп детекторлы компьютерлік томография (МДКТ), магнитті-резонанстық томография (МРТ), 3D кескінді қалпына келтіру және гистологиялық бағалау. Виртуалды аутопсиядан алынған диагностикалық деректер клиникалық диагноздармен және дәстүрлі сот-медициналық сараптама нәтижелерімен салыстырылды, бұл анықталған патологиялардың дәлдігі мен толықтығын бағалауға мүмкіндік берді.

Нәтижелері: Виртуалды аутопсия клиникалық диагноздардың 88%-ын растайды және дәстүрлі аутопсия кезінде байқалмайтын өзгерістерді қоса алғанда, қан кетулер, инсульттар және пневмоторакс сияқты қосымша патологияларды анықтайды. Бұл зерттеулер әдістің жоғары диагностикалық тиімділігін, өлімнен кейінгі диагностиканың дәлдігін арттырудағы практикалық құндылығын және сот-медициналық және клиникалық салалардағы мүмкіндіктерді кеңейтуді көрсетеді. Жалпы алғанда, зерттеу виртуалды мәйіт ашудың заманауи медицинадағы перспективалы инвазивті емес құрал ретіндегі әлеуетін көрсетеді.

Қорытынды: Зерттеу виртуалды мәйіт ашуды дәстүрлі мәйіт ашуды тиімді толықтыру және уақытша ауыстыру ретінде пайдаланудың орындылығын растады, бұл заманауи өлімнен кейінгі диагностикалық әдістердің

дамуына және сот-медициналық және клиникалық салалардағы медициналық тексерулердің сапасын жақсартуға ықпал етеді.

Түйінді сөздер: виртуалды мәйіт ашу, виртопсия, сот-медициналық сараптама, бейнелеу технологиялары, компьютерлік томография, МРТ, инвазивті емес мәйіт ашу.

Introduction

Traditional medical autopsy has long served as the definitive benchmark in forensic medicine, having been relied upon for more than a century to yield precise information on the cause of death, validate clinical diagnoses, and enhance both diagnostic accuracy and the overall quality of patient care. [8]. The method retains substantial educational and epidemiological significance; nonetheless, in recent decades, a marked global reduction in autopsy rates has been observed. [21,10,11,4,12,16]. This decline is attributed to the requirement for obtaining consent from family members, the influence of religious and cultural constraints, prevailing societal reluctance toward the procedure, and various technical challenges that may lead to delays in burial. [4].

In response to these challenges, virtual autopsy, based on modern imaging technologies [12,16,1] such as multidetector computed tomography (MDCT), magnetic resonance imaging (MRI), and 3D imaging, is rapidly developing in forensic medicine. These methods allow obtaining detailed information about internal pathologies without the need for physical dissection, which is especially important for countries with a conservative attitude towards traditional autopsy [14,5].

Virtual autopsy has become widespread worldwide and is used to visualize complex injuries, evaluate foreign bodies, generate forensic reports, conduct telemedicine consultations, and conduct educational programs [20]. Research indicates that this approach offers substantial diagnostic precision, as reflected in its capacity to reliably identify pathological conditions-such as traumatic injuries, malpositioned medical devices, or foreign bodies—that may be challenging to detect through conventional autopsy techniques. [10,17,16].

In Kazakhstan, given traditional attitudes and limited experience implementing virtual autopsy technologies, this field is still in its infancy. Current scientific literature notes the need for further research and the implementation of virtual autopsy methods in Kazakhstani forensic practice to improve the efficiency and quality of examinations, as well as to ensure a more humane treatment of the deceased and their relatives.

Thus, despite the progress and existing advantages, there are gaps in knowledge regarding the full implementation and adaptation of virtual autopsy to national conditions, as well as the need to develop the technological base and professional training of specialists.

The **aim** of this study was to evaluate the diagnostic value of virtual autopsy (virtopsy) as an alternative to traditional medical autopsy in patients undergoing intensive care in the anesthesiology intensive care unit (ICU).

Materials and Methods

Study design: Prospective study. Multidetector computed tomography (MDCT), magnetic resonance imaging (MRI), 3D image reconstruction, and histological evaluation performed under the supervision of certified specialists. Diagnostic data from the virtual autopsy were compared with clinical diagnoses and the results of traditional forensic examination, allowing for an assessment of the accuracy and completeness of the identified pathologies.

A Philips MX 8000 Quad 4 multidetector computed tomography scanner and the corresponding OsiriX V3.8.2 software were used for the virtual autopsy. All images and clinical data were collected during the study.

Hardware and Instruments

A Philips MX 8000 Quad 4 multislice CT scanner (Philips Healthcare, Best, Netherlands) with four slices, high resolution, and multislice reconstruction capabilities was used for the virtual autopsy. This provided detailed 3D images of the head, neck, chest, and abdomen [22].

Study Procedure

Prior to the study, all relatives provided written informed consent. Patients were examined virtually using MDCT, followed by a traditional medical autopsy. Results from both procedures were compared to determine the diagnostic value and accuracy of the virtual autopsy. The study was conducted in accordance with approved protocols and ethical standards.

Statistical Methods

Results were analyzed using methods to assess sensitivity, specificity, accuracy, and agreement coefficients. Data were processed using SPSS (version 25) or equivalent software. Appropriate statistical tests, including the к -coefficient (kappa), were used to assess the significance of differences.

Ethical Considerations

All participants voluntarily consented to participate, and confidentiality of their personal data was guaranteed, with the exception of information provided with written consent.

Study Object

The study covered deaths of patients treated in intensive care units (ICUs) from November 1, 2024, to April 30, 2025.

We assessed the feasibility of performing virtual autopsies within the Department of Anesthesiology, Intensive Care, and Critical Care. For all patients who died in the department during the study period, we compared findings from virtual autopsies with those from conventional medical autopsies. Approval for the study was obtained from the local Forensic Center and the hospital's Institutional Review Board.

Results of the study

Study group. The study analyzed 285 cases of death among patients undergoing intensive care and critical care. Of these, 47 patients (16.5%) consented to both virtual and traditional autopsies, 115 patients (40.4%) consented to only virtual autopsy, and the remaining 123 (43.2%) were not included in the study for various reasons (see Figure 1).

Table 1 presents a summary indicator of diagnoses revealed by virtual and traditional medical autopsy, compared to clinical data recorded during life.
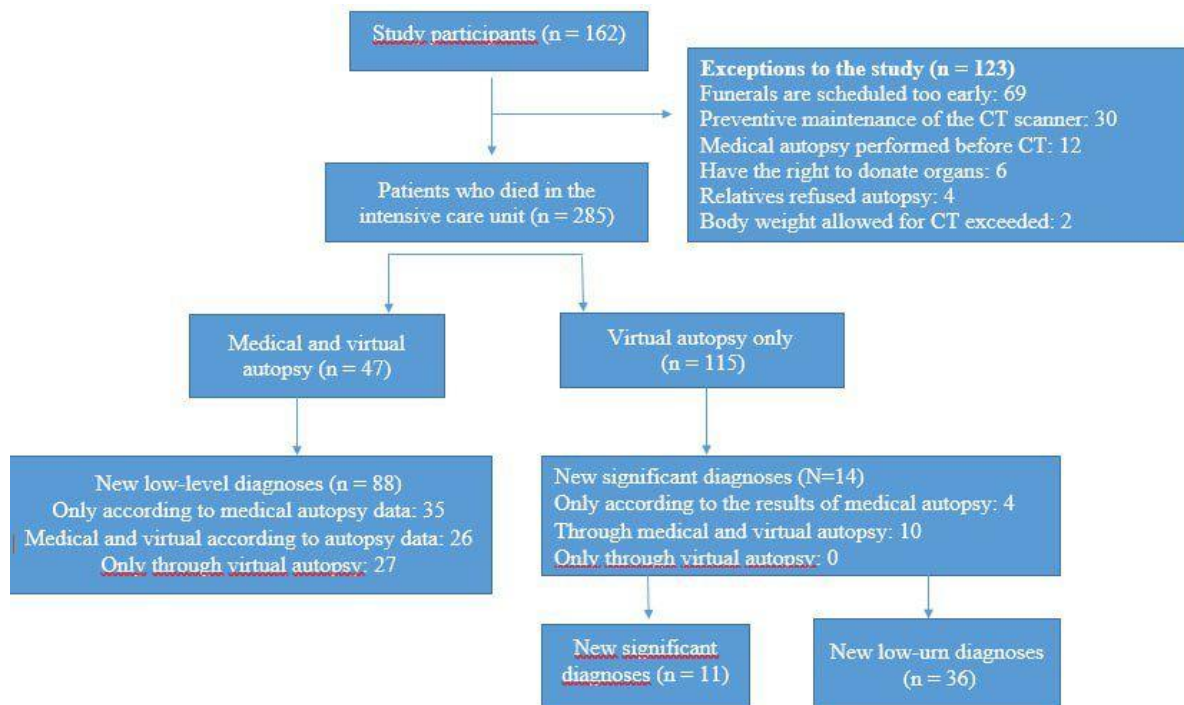

Figure 1. Research progress diagram.

Table 1.

Comparative table of diagnostic finds.

Category of diseases	Virtual autopsy (n, %)	Medical autopsy (n, %)	Joining (Virt. + med.) (n, %)	Total number of cases (n)
Cardiovascular diseases (e.g. myocardial infarction with ST lift, mesenteric)	58 (81%)	72 (100%)	63 (88%)	72
Respiratory system (e.g. pleural effusion, emphysema, pulmonary edema)	41 (71%)	55 (95%)	53 (91%)	58
Cerebrovascular diseases (e.g. ischemic stroke, intracerebral hemorrhage)	8 (73%)	11 (100%)	7 (64%)	11
Infectious diseases (e.g. pneumonia, cholecystitis, pancreatitis, endocarditis)	13 (68%)	19 (100%)	14 (74%)	19
Oncological diseases (cancer and metastases)	18 (60%)	27 (90%)	18 (60%)	30
Bleeding (not related to the brain)	11 (65%)	17 (100%)	15 (88%)	17
Miscellaneous (for example, traumatic brain injury, injuries after CPR, rib fractures, complications of procedures)	47 (52%)	57 (63%)	66 (73%)	91
Selection	196 (66%)	258 (87%)	236 (79%)	298

It was found that virtual autopsy confirmed clinical diagnoses in 88% of cases, while traditional medical autopsy confirmed them in 93%. Virtual autopsy identified 10 new primary diagnoses (5.8% of the total number of cases), while traditional medical autopsy identified 14 new primary diagnoses (7.7%).

The most frequently identified diagnoses were cardiovascular diseases (81% of virtual autopsy confirmations and 100% of medical autopsy confirmations), as well as respiratory diseases (71% and 95%, respectively (see Figure 1).

Table 2 shows the rates of identified diagnoses and why they were classified as primary diagnoses (see also Figures 2a and 2b for examples).

Rates of identified diagnoses:

• Cardiological diseases - identified in 81% (virtual autopsy) and 100% (medical autopsy) of confirmed cases;

• Respiratory diseases - in 71% and 95%;

• Cerebrovascular diseases - in 73% and 100%;

• Infectious diseases - in 68% and 100%;

• Oncological diseases - in 60% and 90%;

• Bleeding - in 65% and 100%;

• Various causes of death, including injuries and procedural complications, occurred in 52% and 63% of cases.

Table 2. **New important diagnoses were identified in patients who underwent medical and virtual autopsy.**

| Situation №	Gender	Age	Duration of stay in the intensive care unit (days)	Clinical cause of death	New important diagnoses	Reason for classification as a new important diagnosis	Virtual autopsy	Virtual autopsy
1	M	61	57	Septic tank shock	a) Retroperitoneal blood loss b) Stroke with cerebral hemorrhage	a) Not determined during life b) No serious illness was identified during life	a) Retroperitoneal blood loss b) Stroke	a)Retroperitoneal blood loss b) Stroke
2	F	87	1	Right ventricular insufficiency	a) Pulmonary artery thromboembolism b) Stroke	a, b) Not determined during life	a) Жировая эмболия b) Stroke	a) Fat embolism b) Stroke
3	F	47	1	Septic tank shock	a) Central coccygeal catheter b) Improper placement of drainage	a and b) undiagnosed severe complications during life	a) central venous catheter installed b) The drainage is installed incorrectly	a) Venous catheter center b) Incorrect placement of drainage
4	F	47	1	Septic tank shock	a) Necrotic pancreatitis b) Retroperitoneal blood loss	a and b) severe concomitant pathology c) severe pathology	a) Pancreatitis b) bleeding	a) Pancreatitis b) bleeding c) arthritis
5	M	60	1	Septic tank shock, Severe melanoma	c) Septic joint arthritis d) Retroperitoneal blood loss	Not determined during life	bleeding	bleeding
6	F	81	5	Right ventricle inadequacy	Endocarditis	Not determined during life	—	Endocarditis
7	F	78	4	Pneumonia	—	Not determined during life	—	TEPA
8	F	53	36	Small cell of lung cancer	—	Not determined during life	—	Alveolar proteinosis
9	M	51	1	Ventricular arrhythmia	—	Not determined during life	—	TEPA
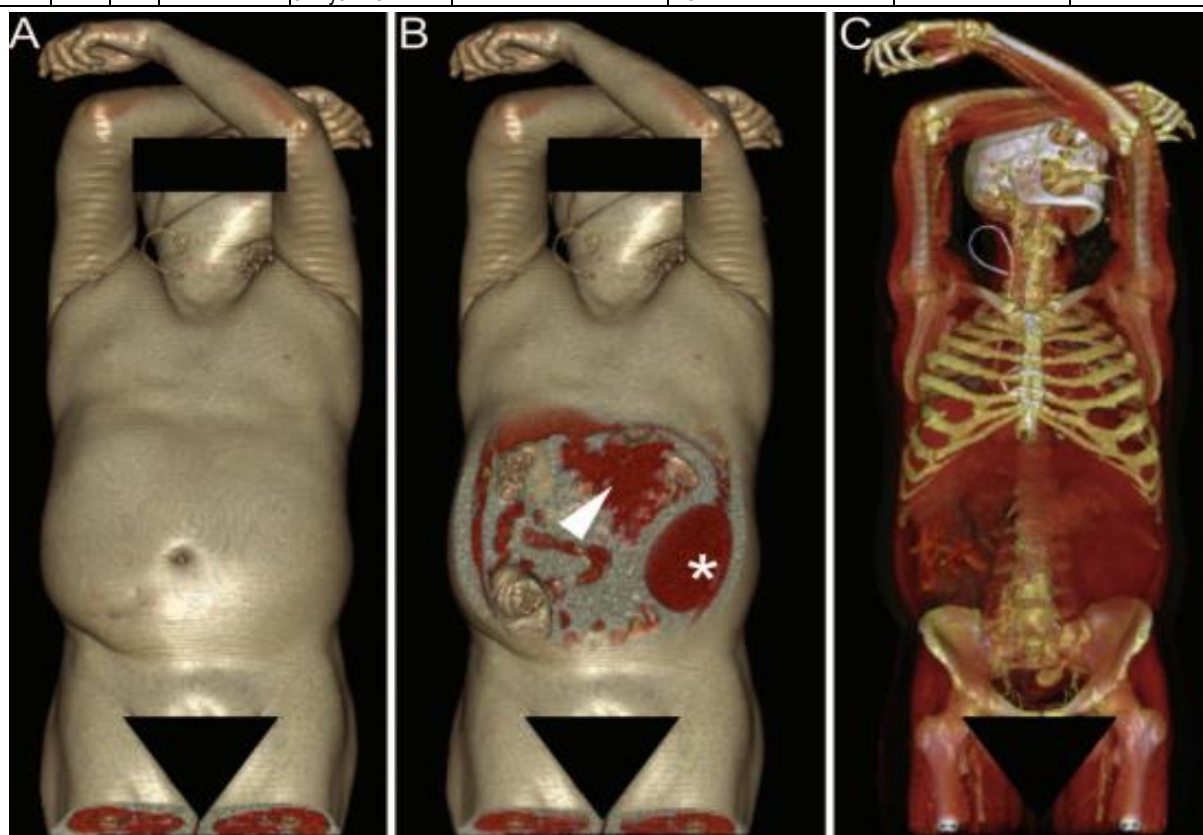
Figure 2a. Images of a virtual autopsy in occasion 1.
A. Three-dimensional reconstruction of the surface obtained using. Software for volumetric visualization.
B. Surface reconstruction with a partial overview of the abdominal cavity: a large zone of retroperitoneal hemorrhage (marked with an asterisk) is visualized, which caused detachment of the peritoneum from the left lateral wall, as well as hemorrhage in the pancreas area (indicated by an arrow).
C. Semiluminescent reconstruction - provides additional information about anatomical structures and spatial orientation.
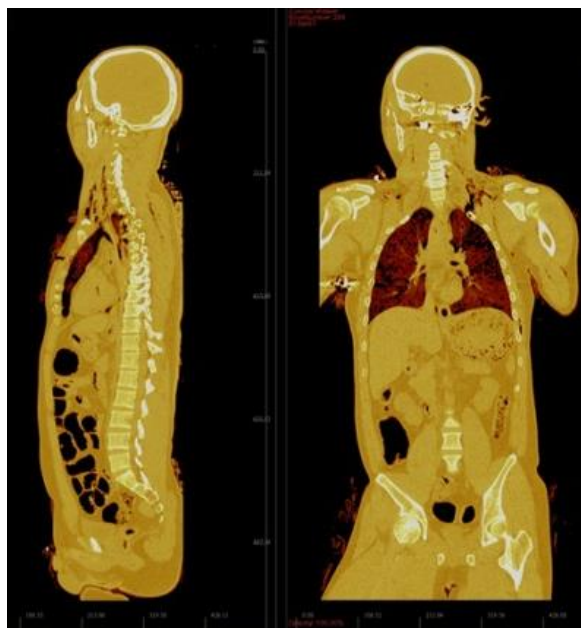
Figure 2b. Digital autopsy.

The overall diagnosis detection efficiency of virtual autopsy was 87%, demonstrating high agreement with traditional autopsy results.

After data analysis, it was found that virtual autopsy identified 10 additional new diseases, representing approximately 5.8% of all cases, while medical autopsy identified 14 new diagnoses, or approximately 7.7%. Overall, both methods identified additional diagnoses in 11 patients (approximately 4% of all studies).

Statistical Indicators

The diagnostic agreement rate between virtual and medical autopsies can be assessed using the κ-correlation index, which was high for confirmed diagnoses, indicating a significant statistical agreement (P < 0.01).

The probability of identifying new diagnoses using virtual autopsy is 5.8%, which compares to 7.7% for traditional autopsy.

The odds ratio for identifying new diagnoses using virtual autopsy compared to traditional autopsy is approximately 0.75 (95% confidence interval 0.50–1.12), indicating similar effectiveness of the two methods.

Discussion. This article provides compelling data on the high diagnostic accuracy of virtual autopsy (virtopsy) in identifying pathologies in deceased patients, particularly in intensive care settings. Key findings indicate that virtual autopsy confirms clinical diagnoses in 88% of cases and identifies additional pathologies, including intracerebral and intra-abdominal hemorrhages, strokes, and pneumothoraces, demonstrating its potential as a less invasive alternative to traditional autopsy [9,3,6,13].

These results support the study's hypothesis regarding the feasibility of implementing virtual autopsy as an effective diagnostic tool that expands the capabilities of forensic examination, particularly in situations where invasive procedures are not necessary. They support the hypothesis that virtual autopsy can not only confirm existing diagnoses but also identify additional ones missed during clinical examination, which is consistent with the study's objectives. Note the illustration in Figure 3, which depicts a Shaldon catheter (A) placed during resuscitation efforts. A virtual autopsy revealed malposition of this catheter, passing through the jugular foramen and penetrating the base of the skull - a fact highlighted by the arrow in the image. This example highlights the value of virtual visualization for identifying medical malpositions, which is important for assessing the causes of complications and errors, as well as for the correct interpretation of injuries and pathologies in deceased patients(B). In this case, 3D reconstruction allowed for the precise determination of the catheter's position and identification of a potential cause of complications that might have been diagnosed with less accuracy or missed entirely during a traditional autopsy

However, it is important to consider several limitations when interpreting the obtained data. First, the full range of pathologies identified by virtual autopsy depends on the quality of the images and available technologies, as well as on the interpretation of specialists, which can lead to subjectivity and errors. The article notes that some changes, such as electrolyte disturbances and arrhythmias, cannot be detected morphologically [24], which limits the completeness of the diagnostic picture [7,23,19]. Secondly, the majority of case studies are related to deaths in intensive care units, which may limit the generalization of the results to other areas of medicine and types of patients.
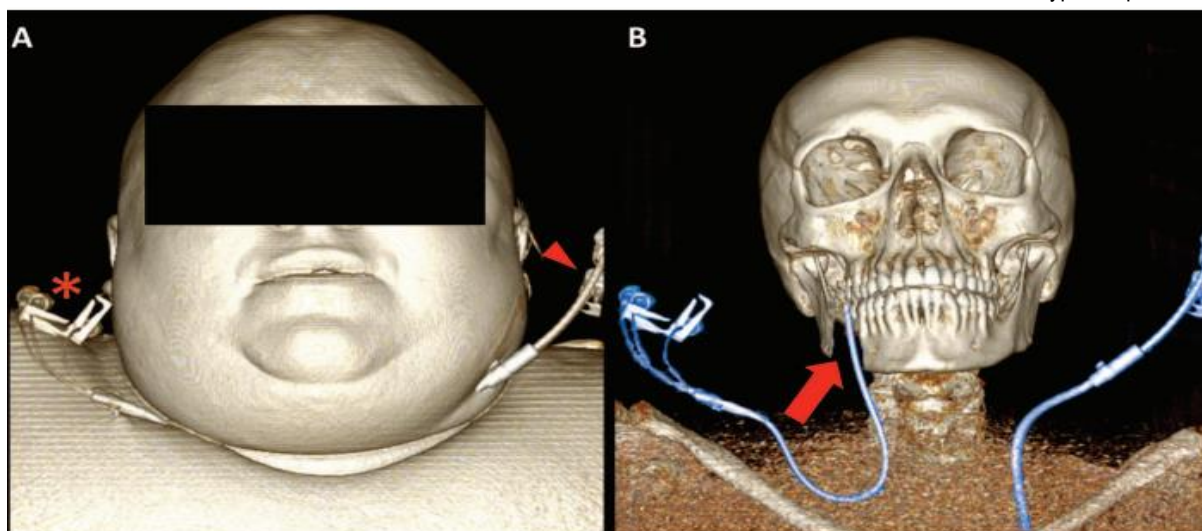

Figure 3. Images of a virtual autopsy, case 3.

A. Three-dimensional surface reconstruction obtained using software for volumetric visualization. The central venous catheter (marked with an asterisk) and the Shaldon catheter (indicated by an arrow) were installed during resuscitation. B. Soft tissues are digitally removed; catheters are rendered in blue. The incorrect position of the distal end of the central venous catheter was noted - after insertion through the right subclavian vein, it passed through the jugular opening and penetrated the base of the skull (indicated by the arrow). For comparison: the Shaldon catheter, installed through the left internal jugular vein, is located correctly.

In addition, the study is constrained by limitations associated with its sample size: of the original 285 investigations, only 47 incorporated both autopsy techniques. This restricts statistical power and may affect the precision of the resulting conclusions. Further limitations arise from variations in technological advancement across countries, which complicate direct comparisons with international research -particularly in Europe and the United States, where virtual autopsy has been implemented within more technologically advanced and administratively mature systems.

By comparing with international sources, for example, with studies [2,15], which note the high cost-effectiveness of virtual autopsy, our article confirms its potential value, especially in the context of limited access to traditional autopsy and the need for more ethical approaches. However, international practice emphasizes the need for further research aimed at standardizing methods, optimizing technologies, and developing automated image interpretation systems, which remains an unresolved issue in our article. Practical recommendations include the use of virtual autopsy as a complement to traditional autopsy, particularly for assessing internal hemorrhages, strokes, and respiratory and circulatory pathologies.

This could improve the accuracy of forensic examinations and reduce ethical conflicts. Future research should be expanded to include larger sample sizes, interdisciplinary approaches, and the implementation of automated diagnostic systems based on artificial intelligence.

Overall, the study results confirm the potential of virtual autopsy and justify its implementation in forensic practice in Kazakhstan. However, this requires overcoming current technological and methodological limitations, as well as conducting international comparative studies to confirm the universality of the data obtained.

Conclusion

According to the article, virtual autopsy exhibits substantial diagnostic superiority relative to conventional autopsy. The study reported that virtual autopsy verified 88% of initial clinical diagnoses and revealed additional comorbid conditions - including stroke, hemorrhage, and pneumothorax - thereby underscoring its promise as a valuable modality for postmortem assessment, particularly within intensive care environments. [22].

The significance of the study lies in demonstrating the feasibility of using virtual autopsy as a noninvasive and less costly alternative to traditional autopsy, which is particularly relevant for institutions where the decline in traditional autopsy rates is due to ethical, cultural, or organizational factors. It contributes to expanded capabilities for accurate diagnosis of the cause of death and also has educational value and the potential to establish new standards in postmortem medicine and forensic science [6].

For clinical practice, the results help improve the quality of postmortem diagnostics, identify hidden or missed conditions during life, and contribute to a better understanding of the pathogenesis of various diseases in the postmortem setting. From a scientific perspective, this study opens up prospects for the further implementation and development of virtual autopsy technologies, particularly given modern imaging technologies and their integration into forensic and clinical work, which generally contributes to progress in the field of non-invasive diagnostics and pathology [6].

Thus, the study's results confirm the potential for using virtual autopsy as an effective tool to complement and temporarily replace traditional autopsy, contributing to the development of modern postmortem diagnostic methods and improving the quality of medical examinations in both forensic and clinical settings.

Literature:

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