International Journal of Medical Toxicology & Forensic Medicine
2026, Volume 16, E52315

Case Report

Complex Analysis and Comparison of Conventional Versus Virtual Autopsy in Case Series of Firearm Head Trauma Produced by Modified Air Gun Rifle and Self-Made Pistol

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Citation Gudelova T, Sotirova M, Fasova A, Hadzhieva K, Dineva P, Yancheva S, et al. Complex Analysis and Comparison of Conventional Versus Virtual Autopsy in Case Series of Firearm Head Trauma Produced by Modified Air Gun Rifle and Self-Made Pistol. International Journal of Medical Toxicology and Forensic Medicine. 2026;16:E52315.

https://doi.org/10.22037/ijmtfm.v16.52315

Article info:

Received: 06 June, 2026

Accepted: 01 August, 2026

Published: 13 September, 2026

Keywords:

Virtual autopsy, Firearm head trauma, Modified air gun, Self-made pistol, Comparison

ABSTRACT

Background: Forensic medicine plays a crucial role in assisting government institutions and in solving complex and unusual criminal cases. With the growing development of technology, this specific subspecialty of pathology is becoming a milestone in determining the key aspects of crime investigation.

Case Presentation: The current case series underlines and shows the importance of integrating both the virtual and conventional autopsy techniques in the field of forensic investigations involving firearm head trauma. The combined application of both methods seriously improves the precision of forensic interpretation and contributes to a comprehensive reconstruction of the mechanism of death. In addition, these cases demonstrate that modified air gun rifles and self-made weapons can cause severe and fatal cranial injuries similar to those produced by conventional firearms.

Conclusion: The current case series underlines and shows the importance of integrating both the virtual and conventional autopsy techniques in the field of forensic investigations involving firearm head trauma. The combined application of both methods seriously improves the precision of forensic interpretation and contributes to a comprehensive reconstruction of the mechanism of death.

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Introduction

Forensic medicine as medical specialty plays a crucial role in helping the government institutions and solving criminal cases. With the growing development of technologies this specific subspecialty of pathology becomes a border milestone in determining the main aspects of crime investigation, especially in interesting and not usual criminal cases. The integration of conventional and virtual autopsy techniques in the field of forensic pathology improves the effectiveness and precision of forensic investigations involving firearm injuries [1, 2]. Conventional autopsy allows thorough internal examination of tissues and organs, whereas virtual autopsy provides advanced imaging capabilities, quick analysis, and long-term digital documentation [3]. When used together, these approaches assist forensic specialists in accurately identifying injury patterns, bullet trajectories, firing distance, and the events leading to death especially in uncommon firearm-related cases [4, 5].

Case Presentation

Case 1

We present a medico-legal case of 57 years-old man who was found dead inside his kitchen over a wooden chair with a death note on the kitchen's table and an air gun rifle near him left on the ground. During the crime scene examination, the distribution of postmortem changes was assessed. Rigor mortis was well fixed, livor mortis was well presented and the cadaver temperature assessed by skin thermometer in the armpits was determined as 29 degrees Celsius. During the detailed examination of the corpse leakages of blood from the nose and both the ears as well as from the mouth were present. During the crime scene examination, a detailed ballistic description of the rifle was made by a ballistic specialist. Examination showed that it was air-gun rifle by factory specification, modified for shooting with conventional ammunitions- 6.5 mm.

The corpse was routinely transferred to the Department of Forensic medicine and Deontology of University Hospital Saint George- Plovdiv for forensic autopsy. Before the conventional autopsy, a CT scanning of the body with 3D reconstruction via Phillips Computed Tomography was performed. The CT scanning over the head region was made with mode of brain visualization and 2 mm slices of interest as specification. The virtual assessment showed a rounded bone defect with diameter 6 mm on the left half of the palate bone with well seen oval deformation from which linear fracture lines were present that coursed through the ethmoidal bone. Additional bone fracture with mosaic pattern was established over the parietal region with bone fragments oriented outside the brain cavity (Figure 1).

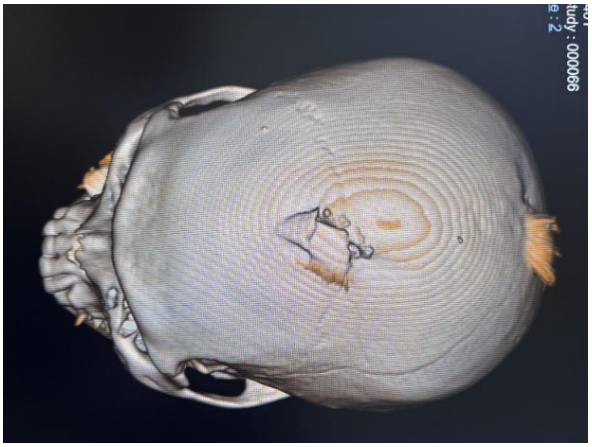

Figure 1. Shows the "Spider-web" fracture of the cranium on CT reconstruction.

A hyperdense foreign body /part of metal projectile/ with unclear shape was seen during the CT scans in the calvarium. Dimensions of the metal fragment were 2×3mm (Figure 2).

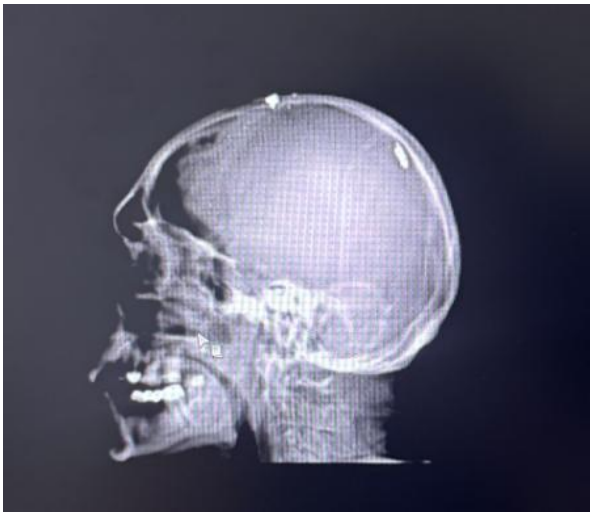

Figure 2. Shows the metal fragments inside the cranial cavity on CT scan.

A hypodense air collection was seen alongside the frontal lobes and on the basis of the brain (Figure 3).

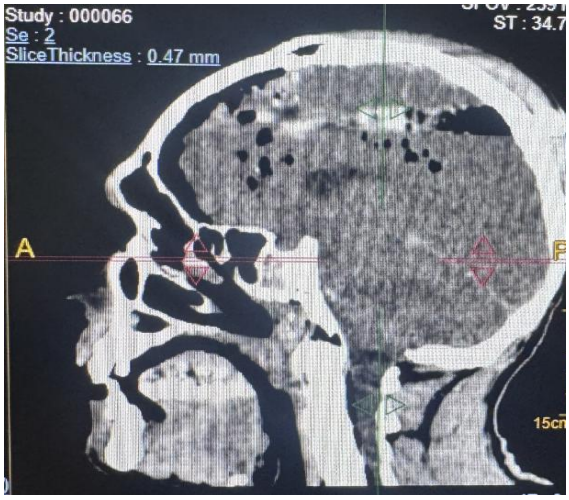

Figure 3. Shows the air collections inside the cranial cavity.

Two hypodense wound tracks with oblique course were seen during the CT scans and the followed reconstructions- one from the ethmoidal bone to the roof of the calvarium and one from the calvarium fracture to the occipital bone, with another metal positive foreign body with almost oval shape which was found just below the inner plate of the occipital bone. The second foreign body was with hyperdense structure and dimensions of 8×9mm.

After the virtual autopsy, a routine conventional autopsy was performed. During the detailed examination of oral cavity, an entry firearm wound with skin defect was seen over the mucosa of palate bone. The entry wound was oval in shape and it had collar of abrasion and collar of dirt. The diameter of the traumatic injury was around 6 mm. The tongue and the

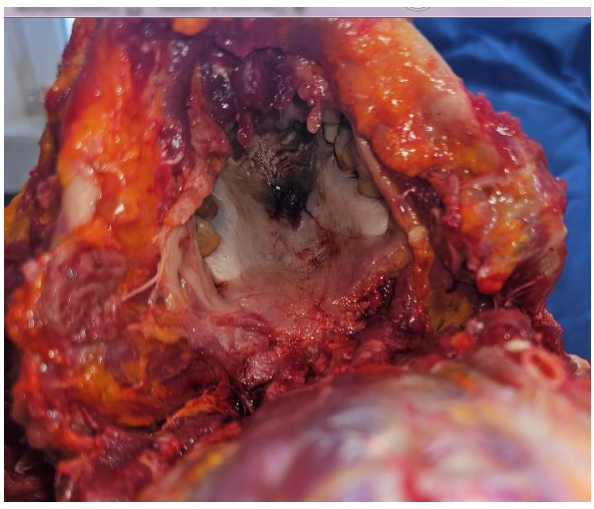

Figure 4. Shows the entry firearm wound inside the oral cavity.

oral cavity were blackened with soot from the muzzle (Figure 4).

Opening of the cranial cavity showed a spider-web bone fracture over the roof of calvarium in the parietal region with fragments oriented outside the brain cavity. From the skull defect a multiple linear bone fracture lines were present which travelled to the base of the skull, went through the occipital, both parietal and both temporal bones (Figure 5).

The cross-sectional view of the fracture showed a cone shaped fracture pattern with the base oriented to the outer plate of the bone. Inside the fracture center, a metal fragment from the projectile was found. The sheet of dura mater was also affected by the projectile. Its dimensions are as described during the virtual reconstructions via CT scans.

Well-developed subarachnoid hemorrhage was seen over both brain hemispheres. The maximum thickness of the subarachnoid hemorrhage was 1 mm, and its dimensions were 15cm x10 cm. Multiple parallel cuts of the brain revealed widespread severe brain destruction with involvement of the brain matter. Disperse contusions over the white matter, grey matter, and inner structures of the brain near the midline were presented. During a thorough examination of dura mater, a metal projectile was found with morphologic description similar to the hyperdense foreign body in the occipital region seen during the CT reconstruction

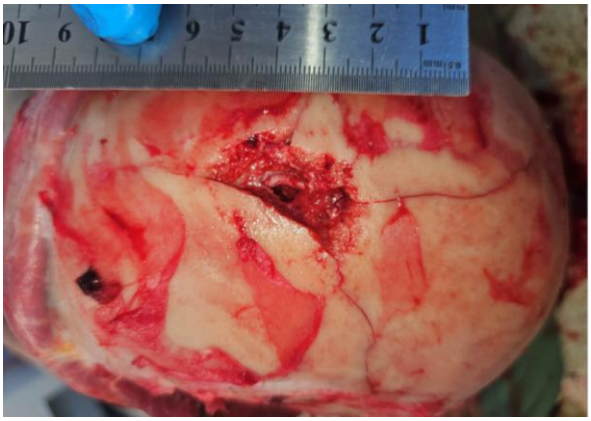

Figure 5. Shows the "Spider-web" fracture of the skull on conventional autopsy.

of the head.

Case 2

We present a medico-legal case of 63 years-old man who was found dead inside his home with no death note left. Near the body was found a self-made firearm (improvised weapon). During the crime scene examination, the distribution of postmortem changes

was assessed. Rigor mortis was not yet present, while livor mortis was well presented. The cadaver temperature assessed by a skin thermometer in the armpits was determined as 33 degrees Celsius. During

Figure 6. The actual self-made firearm (improvised weapon) from the crime scene.

Figure 7. Shows the "comminuted, oval-shaped fracture of the right temporal.

the detailed examination of the corpse, leakages of blood from the nose and both ears as well as from the mouth were present. The entry wound was well visible on the right temporal region of the head, as well as the presence of a muzzle imprint around it. During the crime scene examination, a detailed ballistic description of the self-produced firearm was made by a ballistic specialist. Examination showed that the weapon is fabricated from wooden and metal parts that are not designated for firearm production and was made for shooting with conventional metal ammunitions with 6,5 mm in caliber (Figure 6).

Figure 8. Shows the metal projectile inside the cranial cavity on CT scan.

The body was routinely transferred to the Department of Forensic Medicine and Deontology of University Hospital Saint George- Plovdiv for forensic autopsy. Before the conventional autopsy, a CT scanning of the body with 3D reconstruction via Phillips Computed Tomography was performed. The CT scanning over the head region was made with mode of brain visualization and 2 mm slices of interest as specification. The virtual assessment revealed a comminuted, oval-shaped fracture of the right temporal bone, as well as fractures of the right orbit and the right zygomatic bone as well as right in the middle of the frontal bone beneath the area of the entrance wound (Figure 7).

Bone, as well as fractures of the right orbit and the right zygomatic bone, as well as the frontal bone on CT reconstruction.

A hyperdense foreign body /part of metal projectile/ with unclear oval shape with approximately 4.1 mm in diameter was seen during the CT scans in left middle basilar fossa (Figure 8).

A hypodense air collection was seen alongside the frontal lobes of the brain and a hyperdense bone fragment from the entry wound in the right temporal region (Figure 9).

One hypodense wound track with almost horizontal course was seen during the CT scans and the following reconstructions- from the comminuted, oval-shaped fracture of the right temporal bone on the right through the front and middle basilar skull fossa to the area of the left temporal bone, which was intact.

Figure 9. Shows the air collections inside and the bone fragment from the entry wound in the cranial cavity.

After the virtual autopsy, a routine conventional autopsy was performed. During the detailed examination, the entry wound with the muzzle imprint around it was confirmed on the right temporal region of the head. The entry wound was oval and had a collar of abrasion and a collar of dirt. The diameter of the traumatic injury, in combination with the muzzle imprint, was around 2x2 cm (Figure 10).

Opening of the cranial cavity showed a comminuted, oval-shaped fracture of the right temporal bone, as well as fractures of the right orbit and the right zygomatic bone, as well as a fracture in the middle of the frontal bone, with fragments oriented outside the brain cavity. From the skull defect in the right temporal bone, multiple linear bone fracture lines were present,

Figure 10. The entry wound with the muzzle imprint was in the right temporal region of the head.

which continued in the front and middle basilar fossae of the skull (Figure 11).

Figure 11. The multiple fracture lines of the skull on conventional autopsy.

The cross-sectional view of the fracture showed a cone-shaped fracture pattern with the base oriented to the inner plate of the bone. Inside the left major wing of the sphenoid bone, a metal projectile was found, which was severely deformed. Its dimensions are like the hyperdense foreign body in the left middle basilar fossa seen during the CT reconstruction of the head.

Well-developed subarachnoid haemorrhage was seen over both brain hemispheres. The maximum thickness of the subarachnoid hemorrhage was 3 mm, and its dimensions were 20cm x 15 cm. Multiple parallel cuts of the brain revealed widespread severe brain destruction to the left and right temporal lobes of the brain. Demerger from the bone fragment from the right temporal fracture was also seen in the right temporal lobe. Disperse contusions over the white matter, grey matter and inner structures of the brain near the midline were presented.

The Ethical approval was obtained from the scientific ethics committee, MU Plovdiv (Proposal: 25.04.2025).

Discussion

Virtual autopsy, as a novel method of body assessment, has important scientific and diagnostic value [6-9]. Recent case reports demonstrate the practical value of combining conventional and virtual

autopsy methods in the forensic investigation of firearm-related cranial trauma, especially in uncommon situations involving modified weapons. The injury pattern identified in the present cases was highly unusual because the fatal injuries were produced by an air gun rifle and a self-made firearm. The first weapon was mechanically modified, and the second was completely improvised. Both of them were made to discharge conventional ammunition. Such modifications significantly increase the destructive potential of the weapons and may create injury characteristics similar to those caused by standard firearms [10, 11].

The postmortem CT examination provided important information before the invasive procedure was initiated. The imaging study clearly demonstrated the trajectory of the projectiles, the presence of intracranial metallic fragments, the distribution of the fractures, and the existence of intracranial air collections, which are the main virtual autopsy benefits [12]. Three-dimensional reconstruction also allowed better visualization of the complex fracture morphology and helped determine the direction of force transmission through the skull. In those two cases, virtual autopsy enabled accurate localisation of retained projectile fragments and assisted in planning the subsequent conventional autopsy procedure. The findings from the conventional autopsies confirmed the radiological observations and provided additional macroscopic details that could not be fully assessed by imaging alone. Direct examination of the oral cavity in the first case established the precise morphology of the entry wound and demonstrated soot deposition around the wound margins and inside the oral cavity, findings that strongly supported contact range [13]. Furthermore, the conventional autopsies allowed detailed evaluation of the brain tissue destruction, subarachnoid haemorrhages, dural injuries, and secondary fracture propagation throughout the cranial vault and skull base.

The complementary nature of both techniques became evident during the investigation. Virtual autopsy offered rapid, non-destructive documentation of skeletal injuries and metallic foreign bodies, while conventional autopsy provided direct tissue examination and confirmation of vital forensic characteristics. The combination of both methods improved the overall diagnostic accuracy and contributed to a more complete reconstruction of the fatal events, especially in not-so-commonly seen cases such as those in this case series. In the first case, the metal projectile, by passing through the cranial cavity, generated two metal fragments, which caused a change in the direction of the wound track, which is a relatively rare and casuistic condition commonly seen in the ricocheting phenomenon [14-18]. These types of cases present serious expert difficulty without proper assessment with these two methods of examination /conventional and virtual autopsy/. Another important aspect of the present cases is the forensic significance of homemade or modified firearms. Altered air rifles and self-produced firearms may be underestimated because they are originally designed as low-energy weapons [19, 20]. However, once modified to fire conventional cartridges, they can produce devastating and lethal injuries comparable to those caused by standard firearms. This creates serious medico-legal implications and highlights the necessity for careful ballistic and forensic examination in suspicious deaths involving unconventional weapons.

The present cases also illustrate the usefulness of postmortem computed tomography in documenting evidence that may later assist courtroom presentation and expert interpretation. Digital preservation of findings allows repeated review of the injuries without additional manipulation of the body and facilitates interdisciplinary communication between forensic pathologists, radiologists, and ballistic experts [21].

Conclusion

The current case series underlines and shows the importance of integrating both the virtual and conventional autopsy techniques in the field of forensic investigations involving firearm head trauma. Postmortem CT with three-dimensional reconstruction provides rapid and accurate visualization of fracture patterns, projectile trajectory, retained metallic fragments, and intracranial air collections, while conventional autopsy subsequently confirms these findings and supplies additional information regarding soft tissue injuries, soot deposition, and the extent of brain destruction. The combined application of both methods seriously improves the precision of forensic interpretation and contributes to a comprehensive reconstruction of the mechanism of death. In addition, the cases demonstrate that modified air gun rifles and self-made firearms can both cause severe and fatal cranial injuries similar to those produced by conventional firearms. Therefore, a thorough forensic, radiological, and ballistic assessment remains essential in cases involving unusual or modified weapons.

Acknowledgements

This study is financed by the European Union-NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project № BG-RRP-2.004-0007-C01.

Conflicts of Interest

The authors report there are no competing interests to declare.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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