

Postmortem forensic imaging: An essential tool in contentious cases

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Abstract

Background: Traditional autopsy (TA) is employed towards determining the cause and manner of death. Over the last decade, virtual autopsy (VA), involving the application of forensic imaging techniques have gained prominence and, with great precision in developed countries.

Aim: This is to compare the findings at post-mortem using forensic imaging techniques and, those of TA.

Materials and Methods: Post-mortem CT-Scan and MRI techniques were employed in the present case and for the first time in Nigeria, to identify the fatal injuries and determine their causation. The examination was done prior to the TA; the latter was done by a team of pathologists without the prior knowledge of the imaging findings. The results, using both methods, were subsequently compared.

Results: Most of the VA and TA findings were the same except for the areas that were not readily accessible to the pathology team because of prior embalment of the body. The inexperience of the radiologist in the area of post-mortem forensic imaging also contributed to the few discrepancies.

Conclusion: This is the first virtopsy to be conducted in Nigeria and, with impressive results. The findings compare favourably with those of TA and, have the added advantage of identifying minor injuries that might easily be missed using TA method. Success is however hinged on the expertise of the forensic radiologist and forensic pathologist. While VA can be employed to solve the problems of religious opposition to TA, the cost of the former is astronomical.

Keywords: Traditional autopsy, virtopsy, comparisons, limitations, manner and cause of death

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INTRODUCTION

Autopsy has a checkered history and modern autopsy procedures were performed in the 17th Century by the anatomist of the Renaissance period, Giovanni Morgagni (1682-1771) and celebrated father of anatomic pathology, who wrote the first exhaustive work on pathology.^[1] Since then traditional autopsy (TA) has been in existence both in clinical practice and medicolegal settings.

To enhance diagnostic efficiency of TA, newer forensic fields such as entomology, toxicology, odontology, and more recently, virtual autopsy (VA, Virtopsy) (use of radiologic imaging techniques) have been introduced over time. There has been massive expansion in the use of imaging techniques to assist or supplant TA techniques.^[2] Virtopsy mainly implies the use of imaging techniques such as high-definition multislice computed tomography (MSCT)

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and/or magnetic resonance imaging (MRI) to facilitate autopsy procedures.^[3-5]

The earliest forensic application of VA (imaging autopsy, digital autopsy CATopsy, or virtopsy) was in 1977 when Wullenweber *et al.* used MSCT to describe radiographic patterns of gunshot injuries to the head. Since then, the application of VA in forensic pathology has been on a steady rise.^[6] Virtopsy is usually and best performed before the TA, though at times, VA can be performed after TA to obtain additional information regarding skeletal, muscular, and other anatomic structures not fully examined during the TA.^[3] The advantages of VA are numerous and include the following: investigator independence, objectivity, noninvasive nature, and the fact that radiation dose is inconsequential when performing postmortem imaging studies. In comparison to TA, VA is less time-consuming.^[7,8] The images can repeatedly be viewed, transmitted to other locations while retaining the original details, reviewed by other experts, easily stored, and allows for three-dimensional (3D) reconstruction.^[7] Other applications include the determination of the cause of death, aid in victim identification, and provision of important clues with regard to the mechanism of injury in difficult forensic cases. The latter include severely deformed, burnt or charred remains, identifying distinct foreign bodies such as retained bullets and blades, identification of injuries, medical implants, and forensic reconstructions.^[2,3,7-9] More advantages of VA are demonstration of findings that are not readily recognized during the TA such as air sinuses and small fractures, revelation of unexpected presence of air in various areas of the body, and circulatory system (barring postmortem putrefaction).^[7-9] In TA, forensic findings are documented in an unintentionally subjective (observer dependent) way and findings that have not been documented are irrevocably destroyed if the body has been cremated or disrupted due to destructive techniques used in TA.^[8] Finally, VA is a good substitute when available in situations where TA are rejected by family members or not tolerated by religious inclinations.^[8]

The biggest challenges of VA even in developed settings are logistics and finance. Installing and maintaining VA machines are expensive in terms of both capital outlay and staff costs; the problem is even worse in underdeveloped societies.^[2,8] Other limitations and disadvantages are nondetection of all causes of death (especially natural deaths or deaths due to medical and surgical issues). Needle-guided techniques would still be required to obtain histological samples, and the technique cannot replace toxicological studies where required.^[3,10] Virtopsy has never

been done as part of forensic autopsy in Nigeria and there is no documented case of VA in Sub-Saharan Africa, hence this index case. This study compares the findings in routine TA and VA with a review of the literature.

Case presentation

A 58-year-old male engineer on night duty in an aircraft maintenance hangar was found lying in a pool of his own blood following a loud explosive sound which attracted security men and his colleagues on duty. On arrival, they noticed that the deceased was lying next to a vehicle; he was apparently inflating the vehicle's spare tire (the rim which was now partly dented had been dislodged from the rubber tire component). The nitrogen card machine (normally used to inflate aircraft tires) which he was using to inflate the car tire was still running. His face was severely injured [Figure 1a] and the left hand was partially covering the face. He was taken to a local mortuary, the face was "reconstructed" stitched together, and the body was embalmed [Figure 1b]. Autopsy was subsequently ordered by the coroner and the forensic pathologist in the assembled team requested for a VA before the TA; the family of the deceased were of the opinion that the manner of death was homicidal as opposed to the company's position of an accident. The two procedures were conducted on the same day, 4 weeks after death and following a careful death scene investigation that revealed the damaged rim [Figure 2]. Apparently, the rim had been separated from the tire, flew upward to impact the ceiling, and impacted the victim's face during its downward journey. The findings from both VA and TA are shown and discussed.

MATERIALS AND METHODS

Images were acquired with a 640-slice Aquillon ONE Toshiba CT scanner and 1.5 Tesla Elan Vantage MRI scanner also by Toshiba. The body was wrapped in an



Figure 1: (a) Facial injuries suffered by the victim; (b) reconstruction at the funeral home

artifact-free body bag during the procedure. 5.0 mm unenhanced axial CT cuts of the whole body were taken from the vertex to the toes. Coronal and sagittal reconstructions and 3D volume reformations were also made.

In the case of the MRI, multiplanar T1-weighted, T2-weighted, T2* and fluid-attenuated inversion recovery (FLAIR) sequences of the brain were acquired in addition to sagittal T1 and T2, coronal short tau inversion recovery and 2D as well as sagittal and coronal myelogram images of the cervical spine. The images were reported by a radiologist of 2 years postqualification and with no prior experience in VA. The results of the VA were intentionally not revealed until after the postmortem examination had been completed to avoid any bias and allow for objective comparisons.

The TA was done by the team of pathologists (anatomic and forensic) using the modified Ghon's method of dissection which involves bringing out the organs in systems.

RESULTS

Traditional autopsy findings

External examination

The face was swollen with the presence of 3 major sutured areas with widespread distribution. On removal of the stitches, numerous foreign objects comprising a synthetic foam material, cotton wool, and gauze were observed beneath the facial skin. These had been used to pack and fill up spaces due to tissue defects that resulted from the blunt force trauma. There was an extensive left maxillary fracture extending to the right side and upward to the floor of the left orbital cavity [Figure 3].

There was a big deep wound involving the left mandible, inferior aspect of the right (ipsilateral) orbital bone, and extending through the midline of the roof of the mouth. The medial (inner) border of this wound was formed by the nasal cavity superiorly. The hard palate was completely absent while the tongue served as the floor of this wound. The superomedial border (roof) of the wound was the floor of the orbits. The disruption involved the roof of the left side of the mouth, the left orbital plate and extending across the hard palate and nasal cavity. There was partial disarticulation of the left side of the maxilla that still bore teeth numbers 9–16, numbers 17–21 were not seen, numbers 22 and 23 were present but fractured, number 24 was absent, numbers 25–30 were present, while numbers 31 and 32 were absent. There was silver colored prosthesis in the left upper first and second molars (numbers 14 and 15).



Figure 2: Partly deformed wheel that caused the injuries



Figure 3: Complete disarticulation of facial bones seen at autopsy. There is loss of part of temporal bone

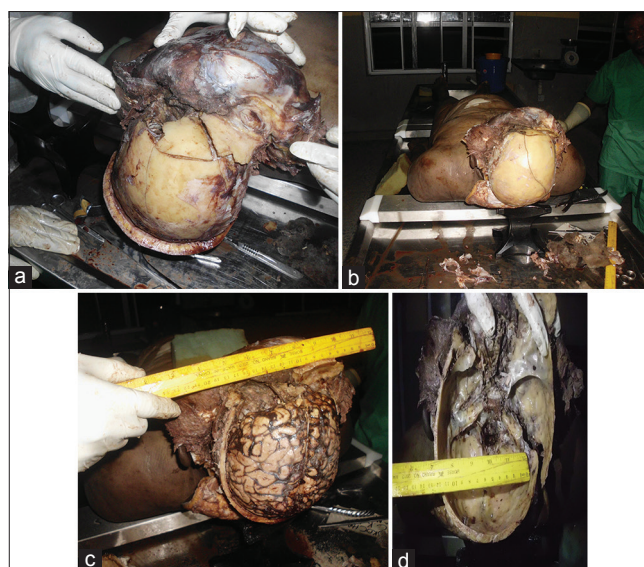


Figure 4: (a) Comminuted frontal bone fractures; (b) oblique linear fracture across both parietal bones, vertex, and base of skull; (c) diffuse cerebral contusion; (d) hinge fracture of base of skull

Following the removal of the stitches from the horizontal wound in the upper part of the face, fracture of the roof of the left orbital bone and left lateral side of the frontal bone were seen.

Skull: There was a coronal fracture measuring 19 cm with a compound comminuted fracture of the frontal bone; the latter is roughly divided into 3 parts with the outermost fragment depressed and penetrating the substance of the left frontal lobe of the brain [Figure 4a-c]. On removing the dura matter, the middle fragment of the frontal bone detached freely. There was a curvilinear nondisplaced fracture extending from the left parietal bone across the midline to the right parietal bone, measuring 15 cm in length; it extends into the right temporal bone over another 6.4 cm [Figure 4b]. Another curvilinear fracture measuring 12 cm was located 8 cm above the occiput and runs through the temporal bone into the ear canal and terminating below it. A hinge fracture is observed, extending through the sphenoid sinus and pituitary fossa in the middle cranial fossa [Figure 4d].

Internal examination

There was subgaleal hemorrhage frontally, with a mild epidural hemorrhage. Most of the left frontal lobe is lost and the adjoining left cerebral hemisphere contains embedded bone fragments [Figure 4c]. There was subdural and subarachnoid hemorrhage around the brain stem, intraventricular hemorrhage (involving the left lateral and 4th ventricles), with petechial hemorrhages in the basal ganglia on both sides. There was severe disruption of the ocular tissue and no vitreous could be retrieved.

The other organs were essentially unremarkable except for the heart that weighed 500g. Overall, the main findings were essentially severe multiple skull and facial bone fractures, lacerations of brain tissue, intracranial hemorrhage, and hypertensive heart disease. Death was attributed to severe

exsanguination due to severe facial and cranio-cerebral injury and sequel to blunt force trauma.

Radiological (virtual autopsy) findings

Multislice computed tomography

Head, face, and neck: There were multiple fractures of the facial bones with depressed components on the left, best depicted on 3D volume rendered images [Figure 5a-e]. The fractures involved the frontal and parietal bones, walls of the orbits, maxillary sinuses with separation of the alveolar process on the left, and the zygomatic bones. There were also multiple fractures of the mandible (with displaced fragments on the right) involving the mental, body, angles, left ramus, and condyle. The left side of face was depressed by 5.8 cm below the right with reference to the interzygomatic line and, the facial structures were deviated to the right. The walls of the left orbit were fragmented and distorted; the left globe was posteriorly retracted with a fairly regular outline and the medial rectus muscle was herniating into the left ethmoidal air cells through its fractured lateral wall [Figure 6a]. There was an irregular area of increased density with Hounsfield unit (HU) of blood in keeping with cerebral contusion or intracerebral hemorrhage in the adjoining lower aspect of the left frontal lobe. There were depressed fractures involving the roof of the left orbit. The walls of the right orbit were also fractured, but its contents were undisplaced. The eye globes were hyperdense suggestive of intraocular hematoma. The frontal and left maxillary sinuses were completely distorted; the walls of the ethmoidal sinuses were compressed, fractured, and deviated to the right. Fracture of the medial and posterolateral wall of the right maxillary sinus with fluid collection was also noted. There was a mildly displaced linear fracture of the left mastoid air cells with fluid collection within it. The nasal septum was deviated to the right but not fractured. There were linear undisplaced high parietal bone fractures and base of skull fracture involving the pterygoid plates (worse on the left), petrous apex, and



Figure 5: (a-d) Three-dimensional view of face

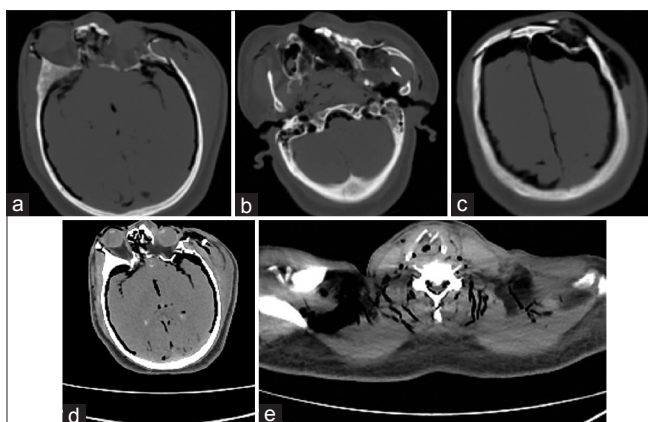


Figure 6: (a) Computed tomography at level of orbit; (b) computed tomography at level of maxilla; (c) computed tomography at level of frontal bone; (d) computed tomography of brain at level of the third ventricle; (e) computed tomography at level of C6 with thyroid cartilage

left styloid process [Figure 6b-e]. Fractures of the maxilla, with the right central dental elements dislodged into the oral cavity, were also seen. There was a spiral laceration of the tongue from the right anterolateral margin extending posteriorly to the base of the tongue.

The brain tissue was retracted posteriorly with loss of gray-white matter differentiation and the sulci, gyri, and Sylvian fissures were effaced. A thin layer of hypodense collection with HU of air was outlining the cerebral hemispheres, falx and tentorium cerebrum, midbrain, and brainstem [Figure 6d]. The ventricles were effaced and contained air and hyperdense fluid. The thyroid cartilage was fractured with posteriorly displaced fragments; the naso-, oro-, and laryngo-pharynx were collapsed [Figure 6e].

Chest, abdomen, and pelvis: Features of decomposition such as the gaseous distension of the abdomen, air within the heart chambers, blood vessels, and soft tissue plains were seen [Figure 7a and b].

The diaphragm was splinted by the gaseous distension of the abdomen. No definitive lung parenchymal injury was noted. The heart size could not be objectively assessed due to the decreased lung volume. However, intraventricular septum and the walls of the left ventricle appear thickened measuring 2 cm and 2.2 cm respectively and, left ventricular lumen was narrowed. The cardiac chambers and great vessels contained air. The bony thorax was normal [Figure 8a-c].

There was no evidence of trauma to the intraabdominal organs. Air within the vessels, urinary tract, and distended bowel loops with evidence of pneumoperitoneum were seen [Figure 8d]. The genitalia were intact.

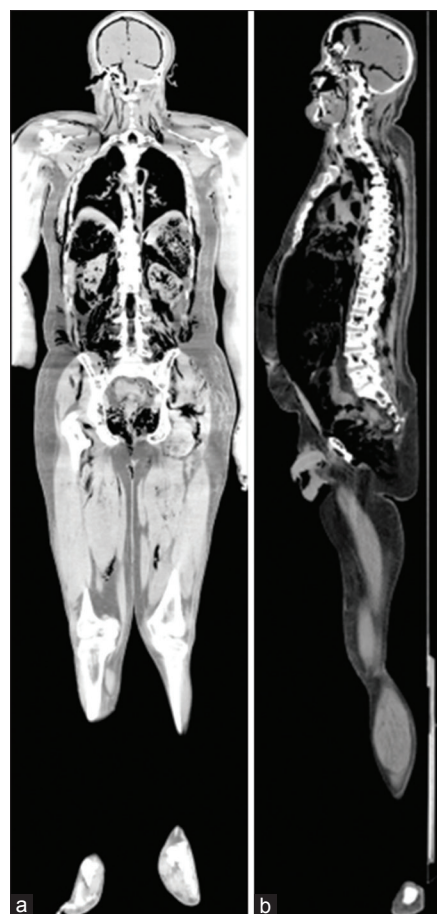


Figure 7: (a) The full body; (b) mid-sagittal view

Spine and musculoskeletal system: Degenerative changes of the cervical and dorsolumbar spine with air outlining the spinal cord within the spinal canal, a vertical fracture of the tip of C6 spinous [Figure 6e] process and streaks of hypodensities within the tissue planes of the neck, chest, abdomen, pelvis, and limbs were seen.

Magnetic resonance imaging of the head and neck

The complex facial bone fractures were poorly delineated. However, there was improved soft tissue detail of the brain. An irregular lobulated area with signal intensity of hyperacute hematoma (intermediate to hypointense on T1 and hyperintense on T2 and FLAIR) was seen in the left frontal lobe extending into the left orbit. The brain was posteriorly retracted; the lateral, third and fourth ventricles and subarachnoid spaces show fluid-fluid levels. The rest of the sulci, gyri, Sylvian fissures, and basal cisterns appeared normal with normal gray-white matter differentiation. Indirect signs of injury such as distorted orbits (left more than right), retinal detachment on the right, herniation of orbital contents into the ethmoid air cells on the left, distorted ethmoid sinuses with deviation to the right, and fluid signal in the right maxillary sinus and left mastoid air cells were

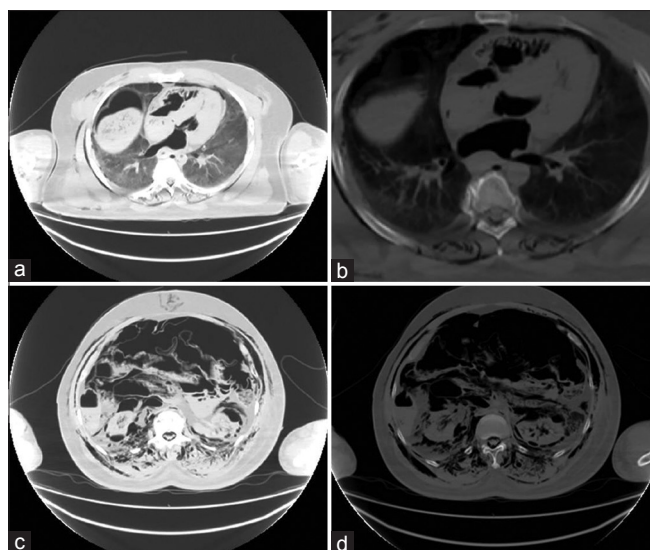


Figure 8: (a) Axial computed tomography at level of lung field; (b) computed tomography at level of cardiac chamber; (c) level of the lung; (d) computed tomography showing air in the pelvic/cecal system

noted [Figure 9a-e]. Fractures of the left mandibular condyle and frontal bone and significant soft tissue swelling overlying the left maxillary and temporalis region were also seen. Based on the above findings, the following conclusions were made:

1. Complex fractures of the face, calvarium, and base of the skull with mixed Le Fort (I-3), tetraploid, naso-orbitoethmoid, left blow out, and mandibular components from a high-velocity blunt impact
2. Features of decomposition.

The spectrum of osseous injuries seen in blunt facial trauma has been described in the past, the classification is based on facial buttress or buttresses affected by each injury pattern with the aim of improving surgical management and detecting associated soft tissue complications.^[11] Multidetector CT is the imaging modality of choice for facial trauma evaluation.^[11] In the index case, the complex facial fractures were excellently depicted on CT while the soft tissue details of the brain and eye globe (right retinal detachment) were seen only on MRI. The presence of multiple fracture types caused by maximal force in different locations of the face implies that the cause of injury was from a large blunt force as have been described in various studies.^[11,12] Involvement of the pterygoid plates implies that Le Fort fracture which are defined fracture lines resulting from force of varying magnitude involving the upper, mid and lower face was likely present.^[11,12] Horizontal fracture of the maxillary alveolar process (Le Fort I), fractures of the medial wall, and floor of the orbit as well as maxillary sinus walls (Le Fort II) and lateral orbital wall and zygomatic fractures (Le Fort III) were seen. Comminuted fractures involving the nasal bones, ethmoid sinuses, and medial orbital walls described as naso-orbitoethmoid

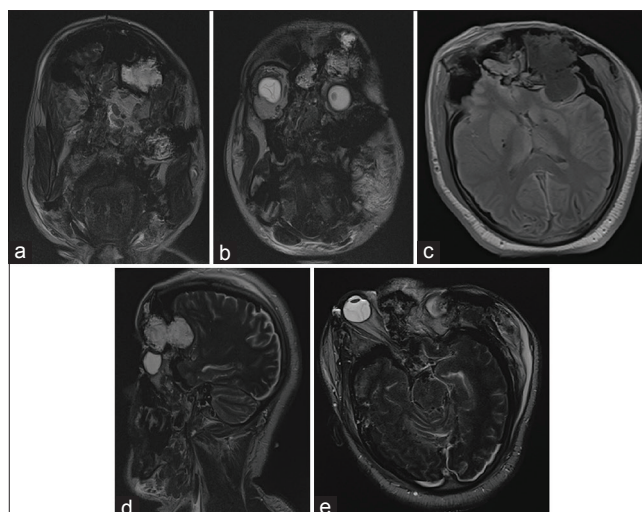


Figure 9: (a) Magnetic resonance at level of orbit; (b) magnetic resonance at level of frontal lobe; (c) magnetic resonance axial image of brain; (d) magnetic resonance sagittal image of brain; (e) magnetic resonance at level of right orbit showing retinal detachment

Table 1: Comparing the findings observed during virtual and traditional autopsies

Pathologies	VA	TA
Facial swelling	+	+
Blow-out fracture of the left eye	++	+
Facial packing materials	+(artefacts)	++
Absent dental elements	++	+
No soft tissue hematoma	+	+
Subgaleal hematoma	+	+
Uneffaced cerebral sulci, gyri and sylvian fissures	+	+
Cerebral contusion	++	++
Basal ganglia petechial hemorrhage	-	+
Air-fluid levels in the ventricles and subarachnoid spaces	++	-
Interventricular hemorrhage	-	++
Air sinuses damage	++	-
Air in cardiac chambers, great vessels and bronchi	++	-
Cardiomegaly	-	++
Left ventricular hypertrophy	++	++
Pneumoperitoneum	++	-
Retinal detachment	+	-
Vertebrae pathologies	++	-
Air around spinal column	++	-

VA – Virtual autopsy; TA – Traditional autopsy; + – Positive finding; ++ – Strongly positive; - – Not observed

complex fractures caused by high impact force applied anteriorly to the nose were present. Zygomaticomaxillary complex fracture caused by direct traumatic blow to the malar eminence with fractures of the zygomatic bone at the zygomaticomaxillary, zygomaticotemporal, zygomaticofrontal, and zygomaticosphenoidal sutures was clearly demonstrated. The right zygomatic bone was clearly seen while the left was fragmented. Other fractures noted were blow out fracture of the left orbit and multiple mandibular fractures which are due to direct force on the eye globe and mandible, respectively.^[11]

The findings during radioimaging were compared with those observed during TA and these are detailed in Table 1.

DISCUSSION

For accurate diagnosis of cause of death following forensic autopsies, radiological investigations and excellent TA techniques are needed. In the index case, the VA diagnosis and TA diagnosis were same and so were the findings, except for few discordance.

Both CT scan and MRI did not recognize the gauze, foam, and cotton wool materials used in packing the face before suturing, rather they were taken to be artifacts. The external description of the facial wounds was more detailed in TA compared to VA in the index case. The greater precision of TA in relation to external examination and the description of lesion vitality have been demonstrated previously by several authors.^[13,14] The extensive pneumoperitoneum, air in cardiac chambers, and air around the spinal cord through the whole spinal column were completely missed (not appreciated) during the TA. Nonvisualization of the spinal cord was quite significant because spinal cord injury which should be better evaluated using MRI-yielded images of no diagnostic value. Spinal cord dissection is not routinely done during autopsy; however, it is quite easy in the hands of the trained pathologist and would be done where indicated. The detection of air in the cardiac chambers, great vessels, bronchi, and pneumoperitoneum are common findings in VA, especially following MSC. This observation is most likely due to postmortem changes. These are rarely appreciated in TA and has been attributed to decomposition and/or air embolism depending on its location and timing.^[9,14] The presence of gas in body tissues limited MRI of the chest, abdomen, and spinal cord in the index case and would reduce the diagnostic yield of VA if the cause of death was to be in these body regions. Some fine details observed in VA were not appreciated on TA and/or may have been lost during dissection. These include fractured 6th cervical vertebrae, damaged air sinuses, completely detached teeth seen in the mouth, fractured thyroid cartilage with posterior displacement, and collapse of the pharynx. Contributing to the nonobservation of all listed above was mainly due to the prior embalment of the body; the stiffness limited the extent of neck dissection and the need for cosmetic considerations. VA missed the basal ganglia petechial hemorrhages, intraventricular hemorrhage in the brain, and the cardiomegaly. The intraventricular hemorrhage described in TA may be responsible for the fluid-fluid levels in the ventricles in the VA, because both pathologies were described at the same location (lateral and third ventricles) in both procedures. The cardiomegaly of 500 g is significant and cannot be attributed to the presence of

gaseous distension alone. The observation of left ventricular hypertrophy by both autopsy methods meant that a cardiac pathology existed. VA has long be known to give excellent diagnosis in trauma-related deaths be it accidents, homicides, or suicides, but not so with natural deaths, especially in cases related to cardiac conditions.^[3]

Due to the complexity of the facial fractures, some of the fractures were better appreciated during a revisit (second look); this is a very important feature of VA which could be technically difficult to achieve using TA method as some vital information may be unintentionally lost during the initial dissection. Furthermore, if the body had been buried, exhumation would have to be ordered to reexamine the body, and this could be officially and socially unacceptable depending on the jurisdiction.

Both procedures agreed on the absence of sharp force trauma despite the artifacts. These conclusions helped convince the family that certain beliefs as to the manner of death were untrue. Of course, the detailed death scene examination further reinforced this conclusion.

Limitations

The logistics of VA was difficult because there were no dedicated machines for postmortem procedures. In places where VA is not routinely done, our experience shows that it could be said to be radiologist and radiology equipment dependent. In other words, it is capital intensive. Stawicki *et al.* earlier made this observation that important questions needed to be answered before more widespread use of VA could be advocated.^[3] These include medicolegal ramifications, medical-economic implications, and issues surrounding radiologic interpretations and experience of the radiologist. In the index case, the equipment were modern, newly acquired and cost of the VA procedure was very high. The radiologist had no prior exposure to postmortem imaging because it is not routinely done. Embalment of the body and the time interval of 4 weeks between death and postmortem studies posed another challenge both for the pathologist and radiologist. Some of these probably in part accounted for different interpretations between the VA and TA findings. The presence of gas from decomposition limited MR imaging of chest and abdomen. The VA procedures were very expensive and cannot be sustained for now in this environment.

CONCLUSION

Combining old well-known TA and VA is synergistic and should be encouraged in Nigeria, since VA offers certain additional advantages. This is the first time that vortopsy will be carried out in Nigeria and the findings

contrasted with those of TA. Nigerian radiologists should be encouraged to explore and subspecialize in this area of medical practice (virtopsy) that has long been practiced in other developed climes. It is anticipated that the economic environment will favor this approach and collaboration between forensic pathologists and forensic radiologists. This is especially desirable in a society still grappling with the acceptability of postmortem examination due to cultural and religious bias. Finally, the employment of VA in the present case reinforced the conclusion as to the manner of death.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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