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Modified whole-body postmortem computed tomography angiography using neck approach

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Abstract

Background The use of radiologic imaging methods in postmortem practice has been advent since the discovery of X-rays. However, with advancement in technology and the emergence of multi-detector computed tomography (MDCT), computed tomography angiography (CTA) and magnetic resonance imaging (MRI) in clinical radiology, several centers around the world have begun using these methods as an adjunct to conventional autopsy. The aim of this study is to introduce a modified protocol for whole-body postmortem computed tomography angiography (PMCTA) based on body weight and neck approach as an alternative to the different PMCTA approaches currently available as most previous studies concentrated on the use of femoral approach for whole-body PMCTA with neck approach for selective or targeted PMCTA.

Methods This was a prospective, double-blinded, cross-sectional study performed on 60 subjects with a mean age of 45.6 years and weight ranging between 43 and 112 kg utilizing ionized water-soluble contrast medium mixed with polyethylene glycol (polyethylene glycol 200).

Results PMCTA using neck dissection showed promising results with good image quality and diagnostic capabilities assisting the forensic pathologists in determining the final cause of death with a strong correlation between both radiologists and pathologists in 86.7% of cases.

Conclusions This study showed that the modified infusion protocol based on body weight using the neck approach provided a good depiction of the vascular system down to the level of the small supplying vessels similar to the other different approaches for PMCTA.

Keywords Postmortem computed tomography angiography (PMCTA), Forensic pathology, Body weight, Modified, Neck approach

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Background

Postmortem computed tomography (PMCT) serves as an adjunct to conventional autopsy and is routinely employed in numerous medicolegal centers worldwide [1, 2]. This is because the images obtained can be used as documentation of a deceased's body condition prior to autopsy [3]. However, it must be remembered that even though PMCT represents the best way to visualize the human skeletal system, this technique has its limitations in terms of vascular and organ parenchyma diagnosis introducing postmortem computed tomography angiogram (PMCTA) to overcome this limitation [4, 5]. The literature has shown that PMCT when used in combination with angiography increases the accuracy in detecting vascular pathologies especially in sudden natural death [6, 7]. There are two types of PMCTA, whole-body and selective angiography [8–10], both of which are ultimately performed in order to assist the forensic pathologist in concluding a cause of death (COD).

The femoral approach is commonly used for whole-body PMCTA while the neck approach is used for selective or targeted PMCTA in western countries. In Malaysia, the neck approach for whole-body PMCTA is more feasible when compared to the femoral approach, as there is no additional incision onto the body besides that which is already being performed during routine autopsy as part of the Y-shaped incision.

Considerable advances in research have been made since the introduction of PMCTA involving research on contrast media, cannulation techniques as well as scanning protocols [11–13]. However, large-scale studies on whole-body PMCTA using the neck approach are scarce. Furthermore, there is no standard or single infusion protocol which is accepted globally with majority of techniques developed using large body weight populations. The techniques therefore employed larger amounts of contrast media due to the larger body weight when compared to, for instance, small-to-medium body weight population in our local setting.

The aim of this paper is to introduce a modified whole-body PMCTA protocol based on body weight using the neck approach.

Methods

Case selection

Subjects were cases brought in dead to the Institute. Decomposed, severely charred and skeletonized bodies were excluded from the study.

Postmortem computed tomography (PMCT) scan

An unenhanced PMCT scan was performed within 6 h of arrival of the deceased to the Institute prior to any body manipulation using a 64-slice (Toshiba Aquilion 64 TSX-101A, Japan) multi-detector computed tomography (MDCT) scanner, a machine wholly dedicated for autopsy use. Subjects were scanned supine from head to toe using 1 mm slice thickness for the head and 2 mm slice thickness for the thorax, abdomen and pelvis down to the toes. Scans were performed using: 120 kVp, Auto set mAs (Caredose), FOV 500 (LL), 1.0 × 32 raw detector collimation and 0.844/standard pitch.

Reconstructions were performed using Osirix software (Pixmeo, Bernex, Switzerland) with a slice thickness of 2.0 mm and slice interval of 1.6 mm in soft tissue and lung window with reconstruction of 0.5 mm thickness for images of the heart.

Cannulation technique

Following the collection of postmortem blood and urine or any other liquid samples deemed necessary like cerebrospinal fluid and vitreous humor for biochemical and toxicological analysis, the common carotid artery (CCA) and internal jugular vein (IJV) of one side were cannulated with a 16F and 18F diameter cannula, respectively (MAQUET Cardiopulmonary AG, Rastatt, Germany).

Access to the internal jugular vein included an oblique incision to the neck, about 5 cm above the clavicle to the lateral side of the neck and dissection of the subcutaneous tissue down to the sternocleidomastoid muscle. The jugular vein was then dissected free and pulled laterally using a string sling. A cut was made horizontally across the anterior wall of the vein leaving the posterior wall intact, to prevent retraction of both ends of the vein. The venous catheter was then inserted while holding the wall of the lower cut aspect of the internal jugular vein with a toothed forceps. The soft tissue was further dissected inferiorly and medially until the carotid artery was located. The carotid artery was dissected free from the surrounding soft tissue and elevated by means of an aneurysm hook with a horizontal cut made across the anterior wall of the artery leaving the posterior wall intact, to prevent retraction of both ends of the artery. The arterial catheter was inserted while holding the lower cut aspect of the carotid artery wall with a toothed forceps aiming to place the catheter tip in the ascending aorta, just above the aortic valve and adjacent to the coronary ostia (Fig. 1).

The tube acting as the inlet was connected to an embalming machine (Portiboy 4) and the outlet tube into an empty container.

Postmortem computed tomography angiogram (PMCTA)

PMCTA was performed using the protocol adapted from the Institute of Forensic Medicine, University of Zurich, Switzerland (Virtopsy® team) and the Victorian Institute of Forensic Medicine (VIFM), Melbourne, Australia.

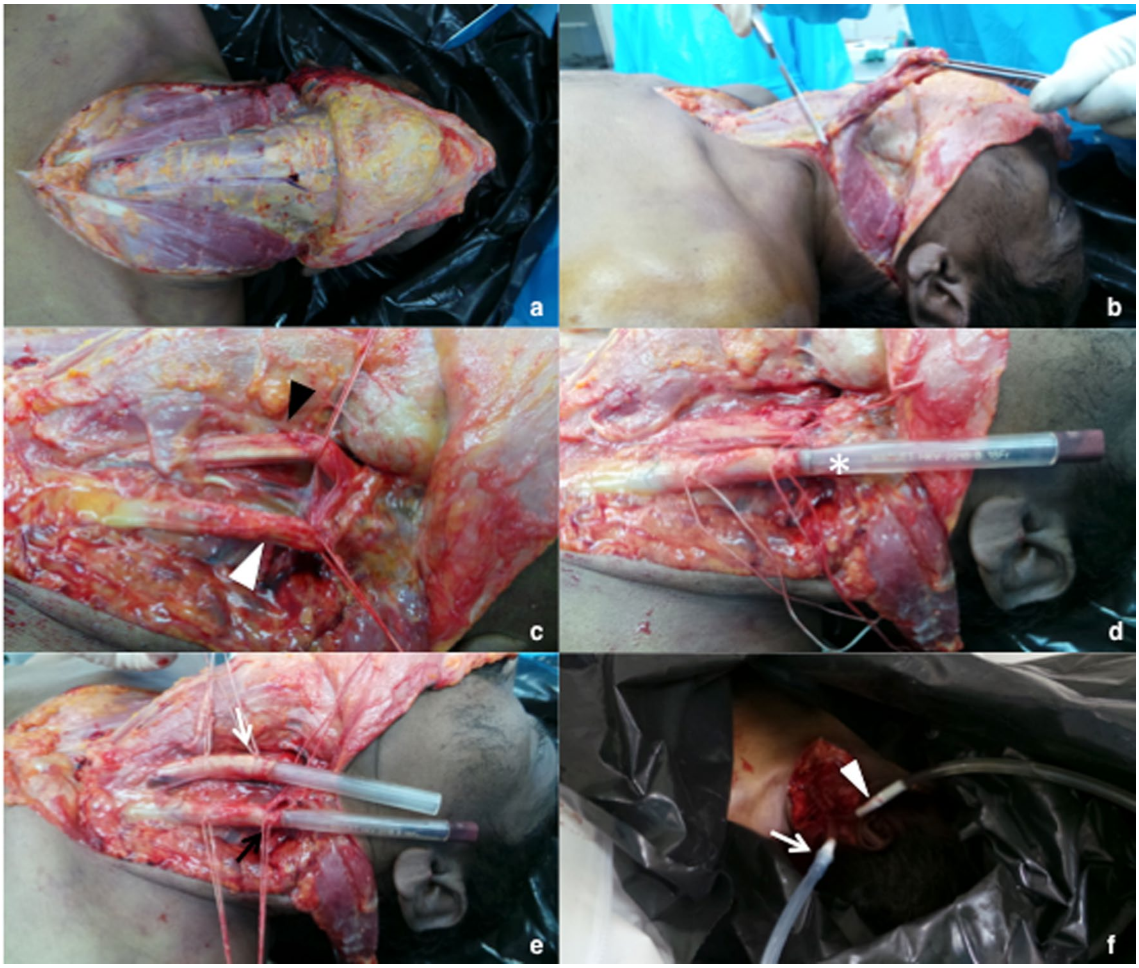

Fig. 1 Cut-down procedure for left-sided cannulation showing the standard Y incision of the neck (**a**). Sharp incision of the subcutaneous tissue soft tissue down inferior to the sternocleidomastoid muscle (**b**). Dissection of the soft tissue to expose the left CCA (black arrow head) and IJV (white arrow head) (**c**). Cannulation of the IJV with an 18-Fr venous catheter as shown by the white asterisk (**d**). Cannulation of the CCA with a 16-Fr arterial catheter and both anchored by strings (white and black arrows) to prevent them from slipping out (**e**). Both the catheters were then connected to the embalming machine for the angiographic procedure. (**f**) Both catheters connected to tubings, one acting as inlet (white arrow) and the other acting as outlet (white arrowhead)

An embalming machine (Porti-Boy Merk VESCO, East Lyme, CT, USA) (Fig. 2) was used to inject the mixture of nonionic, water-soluble contrast medium (Iopamiro 300, Bracco Imaging, Milan, Italy) and clinical polyethylene glycol for synthesis (PEG 200, Merck, Darmstadt, Germany) as a carrier. PEG and contrast were mixed at a ratio of 10:1.

In the initial stage of this study, we used the recommended infusion protocol by VIFM and the VIRTOPSY ® group [14–17]. There were no problems or issues documented in the medium and large body size and weight groups; however, the recommended protocol was not suitable for smaller body size and weight (< 60 kg). The protocol was later modified to accommodate these groups by adjusting the amount of contrast, pressure and infusion rates based on body weight after a pilot project of 20 cases.

The modified infusion protocol was formulated based on the average body weight of the studied population [18]. For the modified protocol, 60 and 100 kg (kg) were chosen as the cut-off point because the average weight of the studied population is 60.6 kg. In addition, with 24.2% of individuals being overweight, 100 kg was chosen as the upper limit [18]. Subjects were divided into three different body size groups, < 60 kg (Small), 61–99 kg (Medium) and > 100 kg (Large).

The amount of contrast media used for each subject undergoing PMCTA depended on respective subject body weight (range 2.5 L–3.8 L) (Fig. 3). The procedure done in three phases included (i) arterial phase infused

Fig. 2 The whole modified PMCTA system was used in our center. The embalming machine was used to inject a mixture of nonionic, water-soluble contrast medium and PEG 200 (no. 1). The inlet and outlet catheters cannulated into the right CCA (for arterial & dynamic phases) and IJV (for venous phase) labeled as no. 2 & 3. Outlet collection container placed on the floor (no. 4) with collection tube attached to the catheters. No. 5 is the pressure and infusion rate regulator and gauge on the embalming machine which controlled the pressure and infusion rate manually during infusion

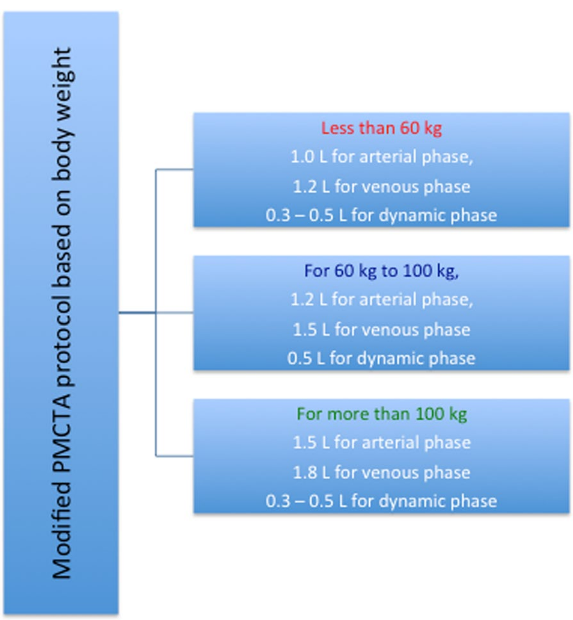

Fig. 3 Modified infusion protocol based on body weight

through the CCA (Fig. 4a) which showed enhancement of the cerebral arteries, thoracic and abdominal aorta down into the femoral arteries bilaterally, (ii) venous phase infused through the IJV (Fig. 4b) which showed venous enhancement of the cerebral, thoracic, hepato-biliary and abdominal vessels down into the femoral veins bilaterally and (iii) dynamic phase infused through the CCA (Fig. 4c) which showed enhancement of the cerebral vessels, pulmonary vessels and inferior vena cava down into the femoral vessels bilaterally. Additional scans if clinically indicated were performed which included lateral, oblique or prone position as well as rescanning of certain body parts.

For arterial phase (1.0–1.5 L), venous phase (1.2 L–1.8 L) and dynamic phase (0.3–0.5 L) of contrast media was used. The pressure and infusion rates were gradually increased from 0 to 80 mmHg and 0–0.5 L/min, for both arterial and venous phases while contrast was injected continuously at a flow of 200 ml/min in the dynamic phase.

For both arterial and venous phases, scanning was done only after infusion of the contrast media in comparison with the dynamic phase when scanning was done during infusion of the contrast media. This was to mimic physiological circulation of the living.

The arterial phase was usually performed first, followed by the venous and dynamic phases. However, in cases of suspected venous pathology, for example, in pulmonary embolism or venous injury, the venous

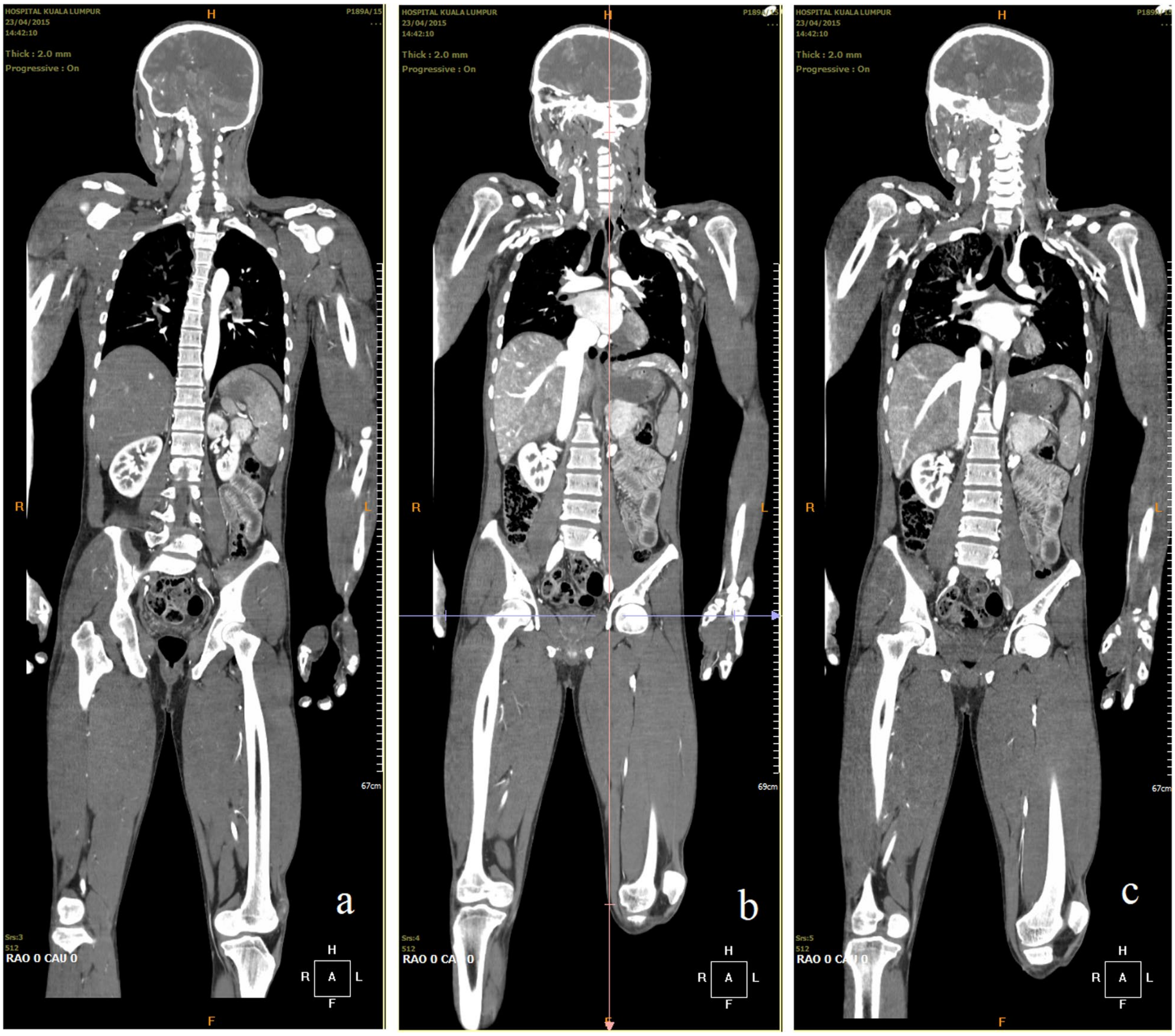

Fig. 4 **a** Whole-body PMCTA image in coronal plane showing left-sided CCA cannulation in arterial phase which showed enhancement of the cerebral arteries, thoracic and abdominal aorta down into the femoral arteries bilaterally. **b** Whole-body PMCTA image in coronal plane showing left-sided IVC cannulation in venous phase which showed venous enhancement of the cerebral, thoracic, hepato-biliary and abdominal vessels down into the femoral veins bilaterally. **c** Whole-body PMCTA image in coronal plane showing left-sided CCA cannulation in dynamic phase infused through the IJV which showed enhancement of the cerebral vessels, pulmonary vessels and inferior vena cava down into the femoral vessels bilaterally

phase was performed first, followed by the arterial and dynamic phases.

Image analysis of Dicom PMCT and PMCTA scan images were performed using Osirix software via multiplanar reconstructions (MPR) by two radiologists with more than 5 years' experience who reported independently of each other. Image quality was based on good and optimum opacification of vessels and organs in all 3 phases.

Standard postmortem examination

Subjects were wheeled back to the autopsy room for a postmortem examination utilizing the standard Y-shaped incision immediately after the PMCTA procedure. The incision made earlier in the neck was extended as well as another was done on the opposite side toward the tragus along the lateral side of the neck, ending just behind the ears forming the forks of the standard Y-shaped incision. The straight line of the Y was then made from the xiphisternum to the pubis in order to expose the organs of the chest and abdominal cavity [19]. The brain and organs of the thoracic, abdominal and pelvic regions were removed and examined as per the usual standard postmortem examination.

Results

The statistical analysis was performed using Statistical Package for Social Sciences (SPSS), version 22.0 (Chicago, IL, USA). Correlation between PMCTA whole-body findings and autopsy was calculated using Pearson's correlation and Chi-square test. A P value < 0.05 was considered significant.

A total of 60 cases were recruited in our study with 46 males and 14 females. The subjects age ranged from 22 to 75 years of age with a mean age of 45.6 years. The time difference between the estimated time of death (TOD) to PMCTA ranged between 2 h and 50 min to 72 h and 9 min with an average time difference of 15 h and 47 min.

The amount of contrast infusion for all 60 cases based on body weight and overall for the arterial phase (AP), venous phase (VP) and dynamic phase (DP) are as shown in Table 1. Whole-body anatomical systems were analyzed and compared to autopsy findings which were considered the gold standard. The strongest correlation involved the central nervous system (98.3%) followed by the cardiovascular (95.0%), vascular (94.5%) and musculoskeletal systems (83.1%). Other systems showed a moderate to strong correlation.

Sokal–Michener similarity coefficient (SC) values or Sokal–Michener simple matching (SM) was used to analyze the dependent variables under investigation as they are binary categorical outcomes. The similarity coefficient (SC) value of both radiologists ranged from 0.890 to 0.889 and the overall SC value for radiologist and pathologist was 0.876, indicating that the image quality obtained was good with excellent diagnostic capabilities assisting the forensic radiologists with their interpretation of organ pathology and formulation of cause of death (COD). There were 47 matched (none discrepancy), 9 minor and only 4 major discrepancies (78.3%, 15.0% and 6.67%, respectively) in terms of the radiologists COD when compared to the pathologist's COD.

Discussion

In Asia in general and most other parts of the world as well religious, social and cultural regulations pose a barrier to autopsy. This has led to a considerable interest toward an alternative technique to autopsy such as PMCT and PMCTA as well as the type of cannulation technique and approach.

The femoral approach for whole-body angiogram is preferred abroad in western countries compared to the neck approach due to its simpler cut-down technique. This is because it can be performed by either a pathologist, radiologist or even a mortuary technician as the cut-down procedure is easy to perform due to the superficially located femoral vessels at the groin. It is also cleaner and faster as the wound is smaller compared to the neck approach [20].

However, in our center, the neck approach was used for both whole-body and selective angiograms to minimize the number of additional incisions performed on the body so as to respect the dead as well as the grieving family members. This is because the incision involving the neck approach is in the line of the Y-shaped autopsy

Fig. 5 Right-side neck incision sutured after a conventional postmortem examination which was in the line of the fork using the standard Y-shaped incision

Table 1 Showing the amount of contrast infusion for all three phases involving 60 cases based on body weight

Group based on bodyweight	No. of cases	Bodyweight in mean(range) (Kg)	AP in mean(range) (L)	VP in mean(range) (L)	DP in mean(range) (L)
Less than 60 kg	15	52.6 (43–60)	1.0 (0.8–1.3)	1.2 (1.1–1.5)	0.4 (0.3–0.5)
60–100 kg	42	73.0 (61–99)	1.2 (1.0–1.5)	1.4 (0.0–1.8)	0.5 (0.3–1.0)
More than 100 kg	3	108 (102–112)	1.4 (1.2–1.5)	1.9 (1.8–2.0)	0.5 (0.3–0.7)
Overall	60 (N)	69.7	1.2 (0.8–1.5)	1.4 (0.0–2.0)	0.5 (0.0–1.0)
Recommended infusion based on previous studies			1.2–1.5	1.5–1.8	0.3–0.5

which is the standard autopsy procedure performed (Fig. 5). Furthermore, the neck approach would be feasible in cases of obesity or previous surgery that could preclude the ability to perform a groin cut down. In addition, the close anatomical proximity between the neck incision, the common carotid artery as well as the internal jugular vein and the mediastinal structures helped provide good enhancement of the central nervous and cardiovascular systems.

Water-based contrast media was preferred over oil-based contrast media because it was readily available in our center in addition to being cheaper when compared to oil-based contrast media. In the initial stage of this study, we used the recommended infusion protocol by VIFM and VIRTOPSY ® group [14–17]. However, we noted a few limitations, complications and pitfalls with this protocol, as it was not designed for the smaller body size population. We believe that it was due to the excessive amount of contrast media and the higher infusion rate and pressure used. There were, however, no problems or issues documented in the medium and large size body weight groups.

The modified protocol using lesser amount of contrast media in the 60.0 kg or lesser group did not affect the image quality and pathological findings diagnosed on PMCTA by the radiologists and confirmed by autopsy.

In general, the image quality and diagnostic value of whole-body PMCTA using neck approach and modified protocol based on body weight was optimal and satisfactory for both the forensic radiologists and pathologists to evaluate and finally conclude the COD similar to other studies [21]. This is evident as both cerebral hemispheres, cardiac chambers and coronary arteries, intra-abdominal organs and the arterial system were well opacified in all groups even at lower amount of contrast media, pressure and rate because of the close anatomical proximity between the neck incision and the common carotid artery as well as the internal jugular vein and mediastinal structures.

There were, however, limitations of this technique which have also been mentioned by other authors which included congestion of the pulmonary vasculature and pulmonary edema (8.3%) of cases, extravasation of contrast media from autolysis and decomposition such as into the digestive lumen, peripancreatic and renal vein and aortic dissection (3.3%) of cases [11, 16, 17].

Conclusions

This new modified infusion protocol based on body weight has proven to deliver promising results without jeopardizing the image quality and diagnostic values of PMCTA even with lower rate and pressure as well as lesser amount of contrast media. It can be used on any population with smaller body size or weight. Radiologists were able to formulate their COD which were comparable to autopsy especially in vascular-related pathology, central nervous and cardiovascular systems with a little drawback involving the respiratory system.

Abbreviations

PMCT	Postmortem computed tomography
PMCTA	Postmortem computed tomography angiography
PEG	Polyethylene glycol

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Author contributions

All authors have read and approved the final manuscript. The contributions of the listed authors are as follows: SNAR was involved in conceptualization, investigation, writing—original draft, writing—review and editing. ACK helped in investigation, writing—review and editing. SSF contributed to conceptualization and writing—review and editing. MRM was involved in writing—review and editing. MKCS helped in conceptualization, investigation, writing—original draft and writing—review and editing.

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Availability of data and materials

The data and material used for this case report are available upon request.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the National Medical Research Register [NMRR ID: NMRR-13-408-14946] and the Medical Research Ethics Committee (MREC). Informed consent was obtained as per the requirements of the MREC.

Consent for publication

Consent for publication is as per the requirements of the MREC.

Competing interests

All authors declare that they have no competing interests or conflict of interest.

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