Postmortem Whole Body CT Angiography Using Aqueous Contrast Agent

7

Guillaume Gorincour, Christine Chevallier, Silke Grabherr, Laure Sarda-Quarello, Christophe Bartoli, Ugo Scemama, Pierre-Eloi Laurent, Frédéric Cohen, Vincent Vidal, and Marie-Dominique Piercecchi-Marti

7.1 Introduction

In modern postmortem imaging, the visualization of the vascular system by postmortem angiography is mostly done using multidetector computed tomography (CT). Like clinical radiologic investigations, whole body angiography makes the vascular system visible and allows identification of vascular lesions such as traumatic dissection or rupture. Additionally, the injection of contrast agent enhances soft tissue and aids in the visualization of lesions in organ parenchyma. In this chapter, we describe two methods of whole body postmortem CT angiography (PMCTA) that can be classed in the category of "PMCTA using aqueous contrast agent."

In the first part, we describe the feasibility of an ultrasound-guided femoral arterial access to perform PMCTA. Femoral arterial vascular access can be achieved under ultrasound guidance followed by a vascular opacification with a mixture of iodine contrast and water. The examination allows diagnosis of arterial lesions confirmed during the autopsy and also depicts venous anatomy. We describe a multiphasic protocol and a secondary technique dedicated to perinatal diagnosis.

In the second part, we report on minimally invasive whole body PMCTA using an aqueous solution mixed with a hyperosmolar substance (polyethylene glycol [PEG]). This technique uses femoral cannulation of one side of the body to access the vascular system and allows injection of the arterial and venous systems. An external perfusion device is used for injecting the contrast agent mixture via the cannulas. The addition of PEG allows the intravascular persistence of the perfusion liquid to avoid edematization of soft tissue.

Both techniques are described briefly, and their possible applications are discussed using case examples.

Today, postmortem multidetector CT (MDCT) angiography (PMCTA) regularly relies on the application of an aqueous contrast agent that can be mixed with a hyperosmolar substance (PEG). Reports from different centers and using different approaches, however, vary in the described injection protocols, contrast agent mixtures, cannulation techniques, and perfusion devices. We discuss in greater detail two approaches that are described most frequently in the literature.

G. Gorincour, MD, PhD (✉) • L. Sarda-Quarello, MD
U. Scemama, MD • P.-E. Laurent, MD • F. Cohen
V. Vidal, MD, PhD
LIIE (Interventional and Experimental Imaging Lab),
CERIMED (European Center for Research in Medical Imaging),
Aix Marseille University, Marseille, France
e-mail: Guillaume.GORINCOUR@ap-hm.fr;
laure.sarda-quarello@ap-hm.fr; ugo.scemama@ap-hm.fr;
pierre-eloi.laurent@ap-hm.fr; frederic.cohen@ap-hm.fr;
vincent.vidal@ap-hm.fr

C. Chevallier
Department of Forensic Imaging, University Center of Legal Medicine
Lausanne-Geneva, Lausanne, Switzerland
e-mail: christine.chevallier@chuv.ch

S. Grabherr, MD, PhD
Department of Forensic Imaging, Forensic Imaging Unit,
University Center of Legal Medicine Lausanne-Geneva,
Lausanne, Switzerland
e-mail: silke.grabherr@chuv.ch

C. Bartoli, MD, PhD • M.-D. Piercecchi-Marti, MD, PhD
Service de Médecine Légale, Hôpital de la Timone,
Marseille, France
e-mail: christophe.bartoli@ap-hm.fr;
marie-dominique.piercecchi-marti@ap-hm.fr

S. Grabherr et al. (eds.), *Atlas of Postmortem Angiography*, DOI 10.1007/978-3-319-28537-5_7

7.2 Postmortem CT Angiography Using Aqueous Contrast Agent

In France, we categorize autopsies into two types: the forensic autopsy, required by a judge (and that no one can object to) to determine the cause and manner of death in cases of unnatural death, and the scientific autopsy, performed for the goal of scientific interest, for which the consent of the family and/or the prospective patient's refusal during his or her lifetime are taken into account [1]. In both cases, autopsy is difficult for the surviving relatives to agree to because of its invasiveness.

In this setting, the contribution of cross-sectional imaging in addition to conventional autopsy has two major advantages. First, it is a noninvasive technique, and second, it allows more objectivity with examinations that are stored and can be reused long after the fact, which is a very important criterion in a judicial process.

Situations in which imaging could replace conventional autopsy are not clearly defined, and the teams working in this area still apply the two approaches simultaneously so that the accumulated scientific data can be used to specify the respective indications. Because of the absence of contrast material injection, the contribution of postmortem CT or PMCT to the postmortem diagnostic approach has been limited in the analysis of vascular lesions [2].

The Virtopsy group (www.virtopsy.com) was the first to publish technical data on PMCTA. In their team, injection is carried out with a surgical approach following the Scarpa triangle: incision, dissection, and cannulation of the femoral vessels (arteries and veins). The injection consists of a mixture of water-soluble contrast agent and PEG (PEG 200, Schaerer and Schlaepfer AG, Rothrist, Switzerland) [3–5] with a volume of 2000 mL injected at 0.6 L/min through a heart–lung machine.

The use of PEG with a water-soluble contrast medium makes it possible to obtain real parenchymographies through the low molecular weight of the contrast agent. In addition, because of the high molecular weight of the PEG, extravasation resulting from autolysis or decomposition, mainly in the pancreas and gastrointestinal tract, can be avoided. The only disadvantage of this type of opacification is that the acquisition must be done quickly or it becomes difficult to differentiate the arterial system from the venous system. At the time we wanted to develop PMCTA in our institution, we had neither the MDCT unit nor a heart–lung machine available.

As far as perinatal pathology is concerned, a worldwide decrease in parental agreement to autopsy and a shortage of trained specialists have been observed, indicating the need to develop alternative methods to avoid losing medical information of paramount importance regarding further genetic counseling. There are few published data about PMCTA in perinatology [6, 7], where magnetic resonance imaging (MRI) is the most studied modality. Our objectives were also to study the feasibility of a simplified method extended to perinatal PMCTA.

Eventually, continuous learning of PMCT semiology is essential through a constant multidisciplinary discussion between forensic pathologists and radiologists regarding the data.

7.2.1 Methods

7.2.1.1 Trauma, Ballistic, and Unexplained Death Cases

We perform PMCTA using a dual-source 64-slice scanner (Siemens Medical Systems, Erlangen, Germany) with a protocol that includes an initial whole body acquisition without contrast media. Basically, the right femoral artery is punctured under ultrasound guidance using an 18 G catheter, then catheterized using a hydrophilic 0.035 guide. A test injection is conducted with a 6 F valve introducer. Depending on the timing between death and the use of CT, we also can use a micropuncture kit (SKATER Introducer, Angiotech, Reading, PA), which provides a flexible tip and is hardly traumatic. In the absence of current published data on this new technique, our protocol is to inject the maximum volume permitted by the syringe pump normally used for CT injection in a living patient, i.e., 2×200 mL. Thus, a mixture of 400 mL with 50 % water: 50 % water-soluble iodinated contrast (Iobitridol 300 mg/L, Xenetix, Guerbet Laboratories, Villepinte, France) is injected using the syringe pump, with a rate of 10 mL/s. The whole body acquisition begins immediately after the end of the injection (40 s after starting the injection). The acquisition parameters are 140 kV, 420 mAs, collimation 64×0.6, and rotation time of 0.5 s. Reconstructions are performed with slices 1.25-mm thick in mediastinal windows, parenchyma, and bone. With growing experience, we have progressively introduced a second injection and acquisition in a prone position and a third (and last) injection and acquisition in a supine position. The time required for completion of the entire procedure is estimated at 45 min [8].

7.2.1.2 Perinatal Cases

Our vascular catheterization technique [9] uses a 22-G peripheral vein catheter (ProtectIV Plus Safety I.V. Catheter, 22 gauge, Smith Medical International Ltd, Rossendale, Lancashire, UK) inserted into the umbilical vein. We manually inject a mixture of 60 mL/kg of water (50 %) and iodine contrast (50 %, Iobitridol 300 mg/L; Xenetix, Laboratoires Guerbet, Villepinte, France), first in the supine position. After the first attempts, our technique was modified to half the injection in the supine and half in the prone position, and then modified again so that during the whole duration of the injection, we perform two procubitus/decubitus full rotations of the fetal body according to the crown–rump axis [10]. Bodies are scanned with the same CT device (Definition 64, Siemens, Erlangen, Germany) using the following protocol: 100 kV, 250 mAs, collimation 64×0.6, and a rotation time of 0.5 s. Reconstructions dedicated to the mediastinum, lung, and bone are performed at 1.25-mm thickness. Each body is scanned before and then after contrast injection.

We advocate that CT could be an attractive technique because its spatial resolution is greater than that of MRI, and bone and proximal aerodigestive tract analysis can be accurately obtained on a first acquisition without contrast media, always performed within our protocol. The umbilical vein could definitely be an attractive pathway to inject contrast medium because it is larger than the umbilical arteries, is easier to check with ultrasound in case of doubt concerning the position of the catheter, and has a shorter pathway to the heart through the ductus venosus. In addition, there is a theoretical higher probability of arterial and venous filling through both the foramen ovale and the ductus arteriosus.

This new technique, in combination with others (especially ultrasound), will become increasingly complementary in the field of fetopathology. For vascular and cardiac examination, the spatial resolution of CT and the ability to obtain an intravascular contrast might make it superior to MRI.

7.2.2 Case Reports and Figures

7.2.2.1 Case 1: Adult Motor Vehicle Trauma

Three-dimensional volume rendering (VR) bone reconstruction of non–contrast PMCT shows fractures of the scapula (*red arrow*) and ribs (*white arrows*) (Fig. 7.1a) and posterior mediastinal hematoma (*arrows* in Fig. 7.1b). Three-dimensional multi-intensity projection (MIP) reconstruction after test injection demonstrated extravasation of contrast medium after our first attempt at femoral artery puncture with ultrasound guidance (Fig. 7.1c). Three-dimensional VR skin reconstruction depicts the two introducers after a second successful contralateral attempt at femoral artery puncture (Fig. 7.1d). An axial image of PMCTA at the same level as in Fig. 7.1b clearly delineates extravasation through both the aorta and a pulmonary vein (*arrows* in Fig. 7.1e). Parasagittal MIP reconstruction better delineates extravasation (*arrow*) through the ruptured thoracic aorta, explaining the posterior hematoma (Fig. 7.1f).

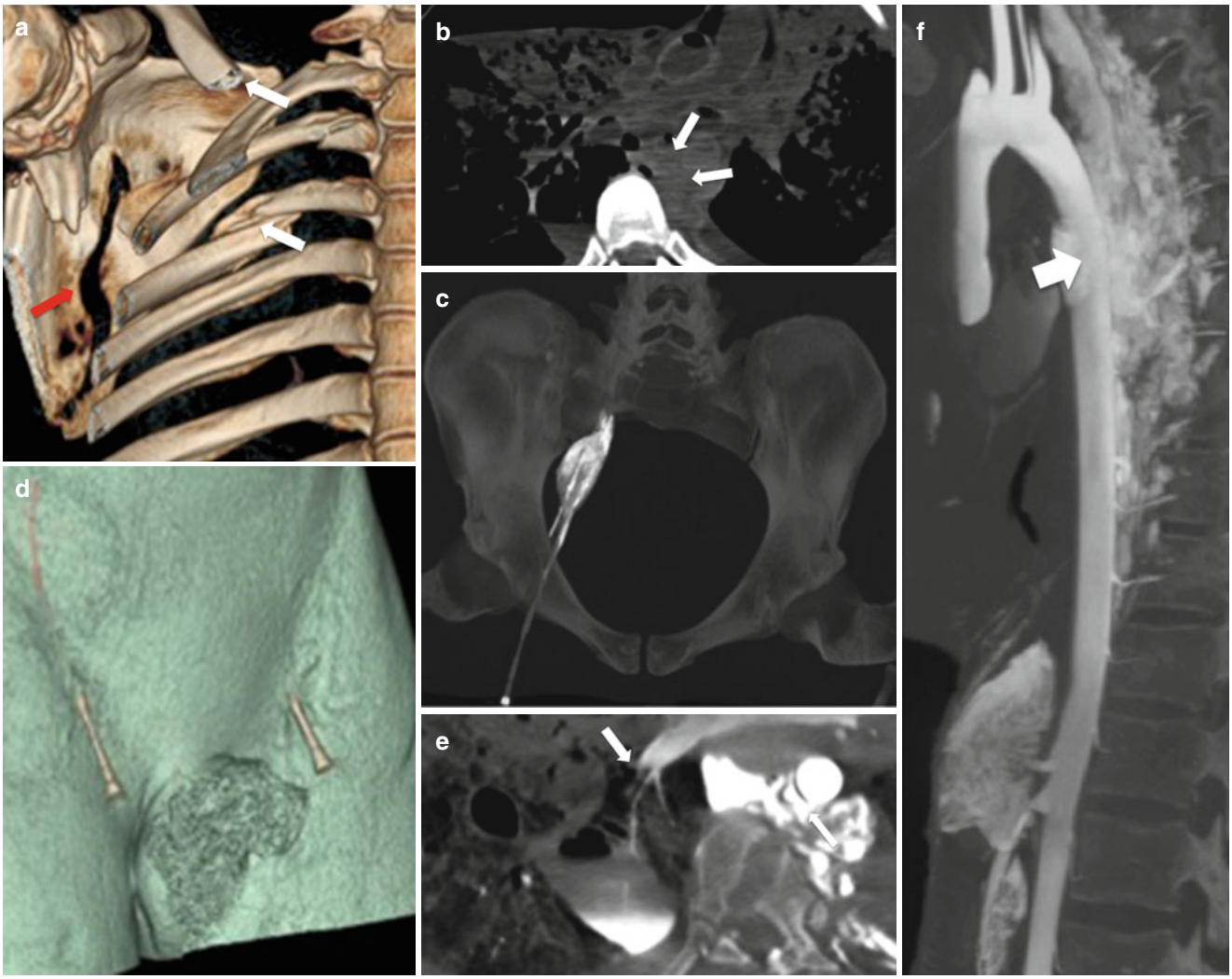

Fig. 7.1 Fractures of the scapula (*red arrow*) and ribs (*white arrows*) (**a**) and posterior mediastinal hematoma (*arrows* in **b**). (**c**) Extravasation of contrast agent after attempt of femoral artery puncture shown on a mip (multi-intensity reconstruction) of the pelvis. (**d**) 3D volume rendering (vr-image showing intoducers in both femoral regions. (**e**) Axial image showing extravasation (*arrow*) originating from the aorta and a pulmonary vein. (**f**) Aortic rupture (*arrow*) with extravasation of contrast agent in a parasagittal mip-reconstruction

7.2.2.2 Case 2: Adult Found Dead at Home

Three-dimensional VR bone reconstruction of non–contrast PMCT exhibits intrauterine disposal (*arrowhead*), umbilical piercing (*white arrow*), and a left femoral catheter (*yellow arrow*) in the correct position (Fig. 7.2a). Coronal reconstruction after the first (supine) injection and acquisition delineates the arterial vasculature and early beginning venous opacification very well (Fig. 7.2b). Coronal reconstruction after the second (prone) injection and acquisition still shows good arterial filling and improved venous opacification, as in the distal inferior vena cava (*cross* in Fig. 7.2c). Coronal reconstruction (at the same level as in Fig. 7.2b) after the third (supine) injection and acquisition demonstrates late venous opacification (Fig. 7.2d). Examples of multiplanar oblique maximum intensity projection (MIP) reconstructions after the third injection and acquisition delineate arterial and venous anatomy as depicted by our less invasive technique (Fig. 7.2e).

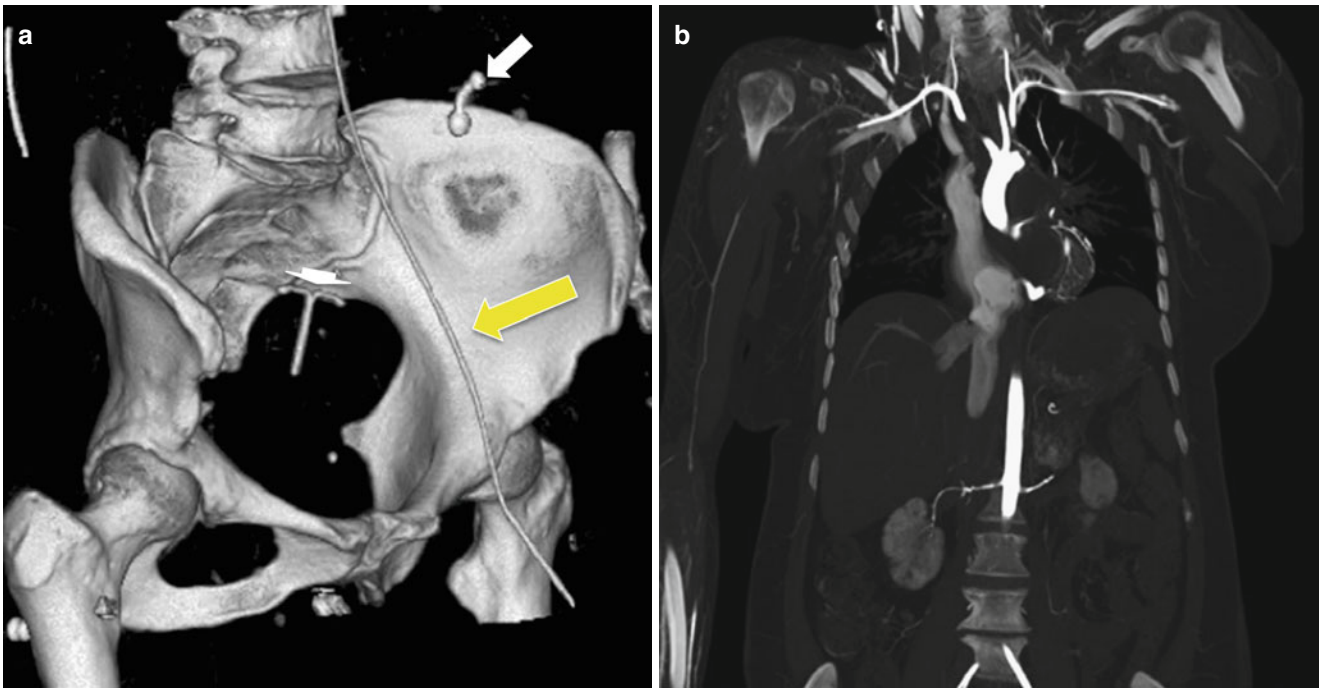

Fig. 7.2 (**a**) Intrauterine disposal (*arrowhead*), umbilical piercing (*white arrow*), and a left femoral catheter (*yellow arrow*) in the correct position. (**b**) Arterial vasculature and early venous opacification. (**c**) Good arterial filling and improved venous opacification, as in the distal inferior vena cava (*cross*). (**d**) Late venous opacification. (**e**) Arterial and venous anatomy

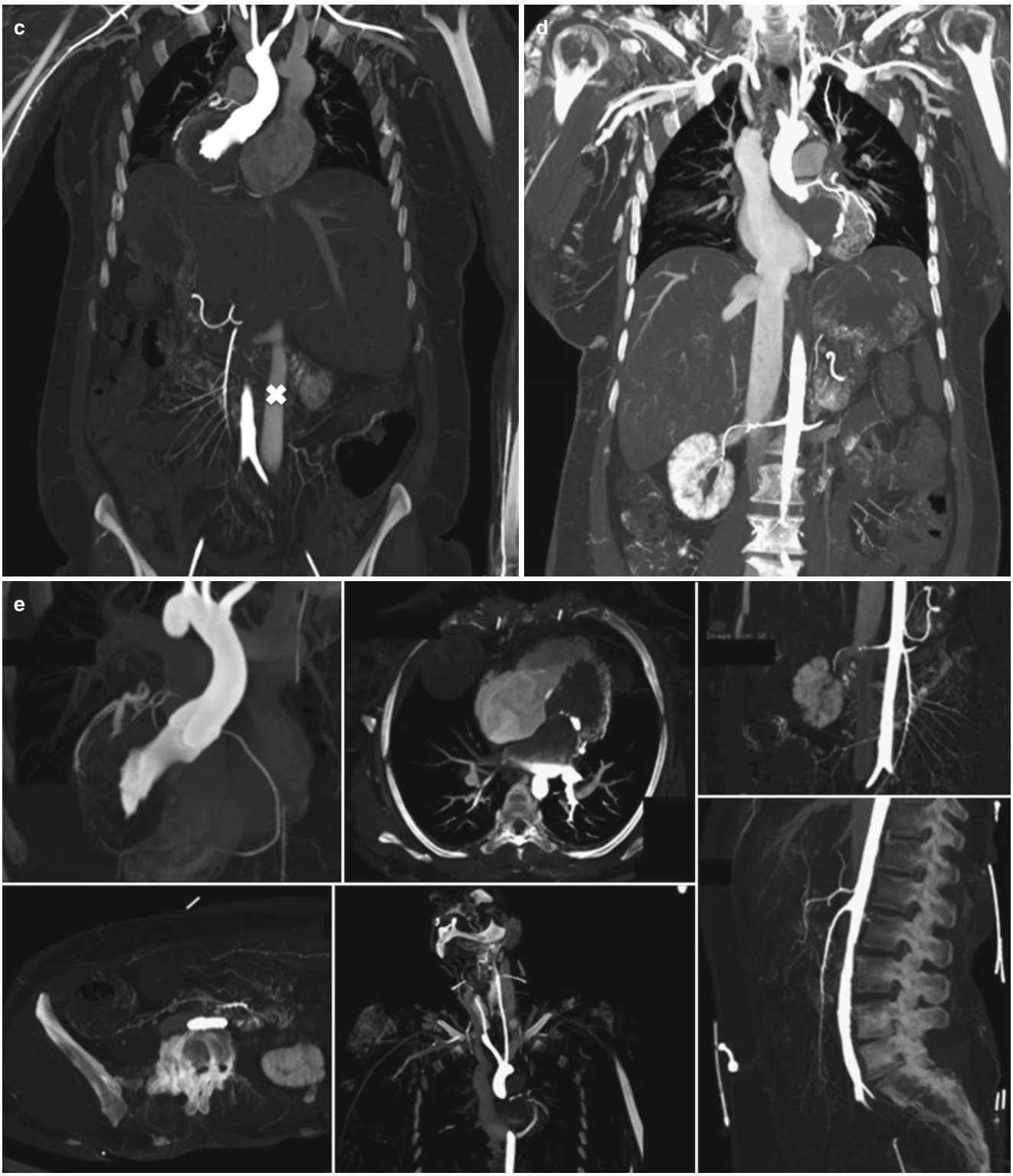

Fig. 7.2 (continued)

7.2.2.3 Perinatal Death Cases

Three-dimensional MIP reconstruction of perinatal PMCTA exhibits normal arterial and venous anatomy of all fetal organs (Fig. 7.3a). Coronal reconstruction shows both normal postmortem heterogeneous liver enhancement and artefactual intraperitoneal extravasation (*arrows*) by secondary rupture of the umbilical vein during the last part of the injection (Fig. 7.3b). In the same patient as in Fig. 7.3b, coronal reconstruction demonstrates normal systemic venous return through the superior vena cava (*star* in Fig. 7.3c). In a different fetus, an axial image delineates arterial anatomy of the Willis circle (Fig. 7.3d). In the same patient as in Fig. 7.3d, sagittal reconstruction illustrates normal brain venous anatomy (Fig. 7.3e). In a different patient, sagittal reconstruction shows extravasation with the pericerebral spaces (Fig. 7.3f).

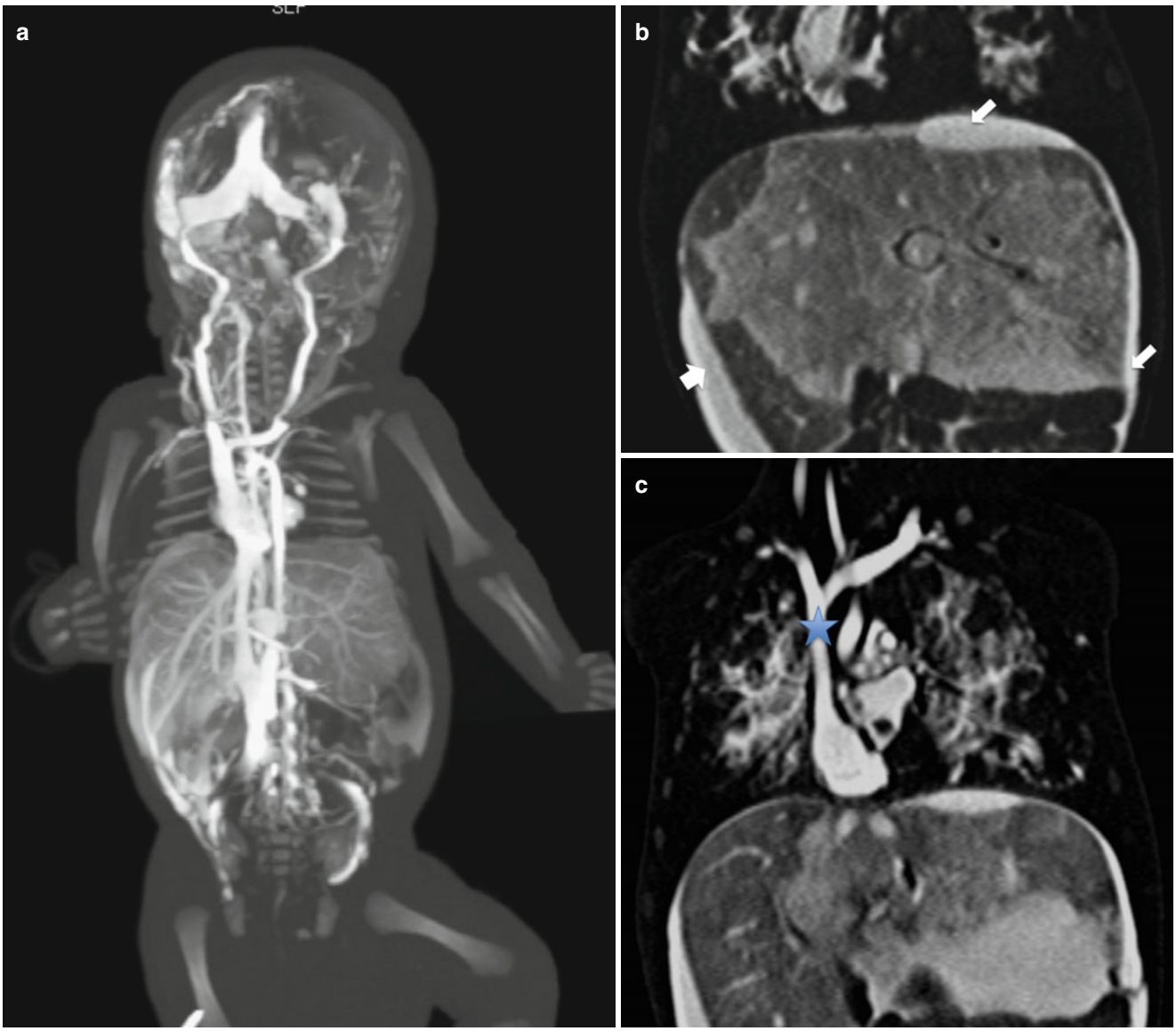

Fig. 7.3 (**a**) Normal arterial and venous anatomy of all fetal organs. (**b**) Normal postmortem heterogeneous liver enhancement and artefactual intraperitoneal extravasation (*arrows*) by secondary rupture of the umbilical vein. (**c**) Normal systemic venous return through the superior vena cava (*star*). (**d**) Arterial anatomy of the Willis circle. (**e**) Sagittal reconstruction illustrates normal brain venous anatomy. (**f**) Sagittal reconstruction shows extravasation with the pericerebral spaces

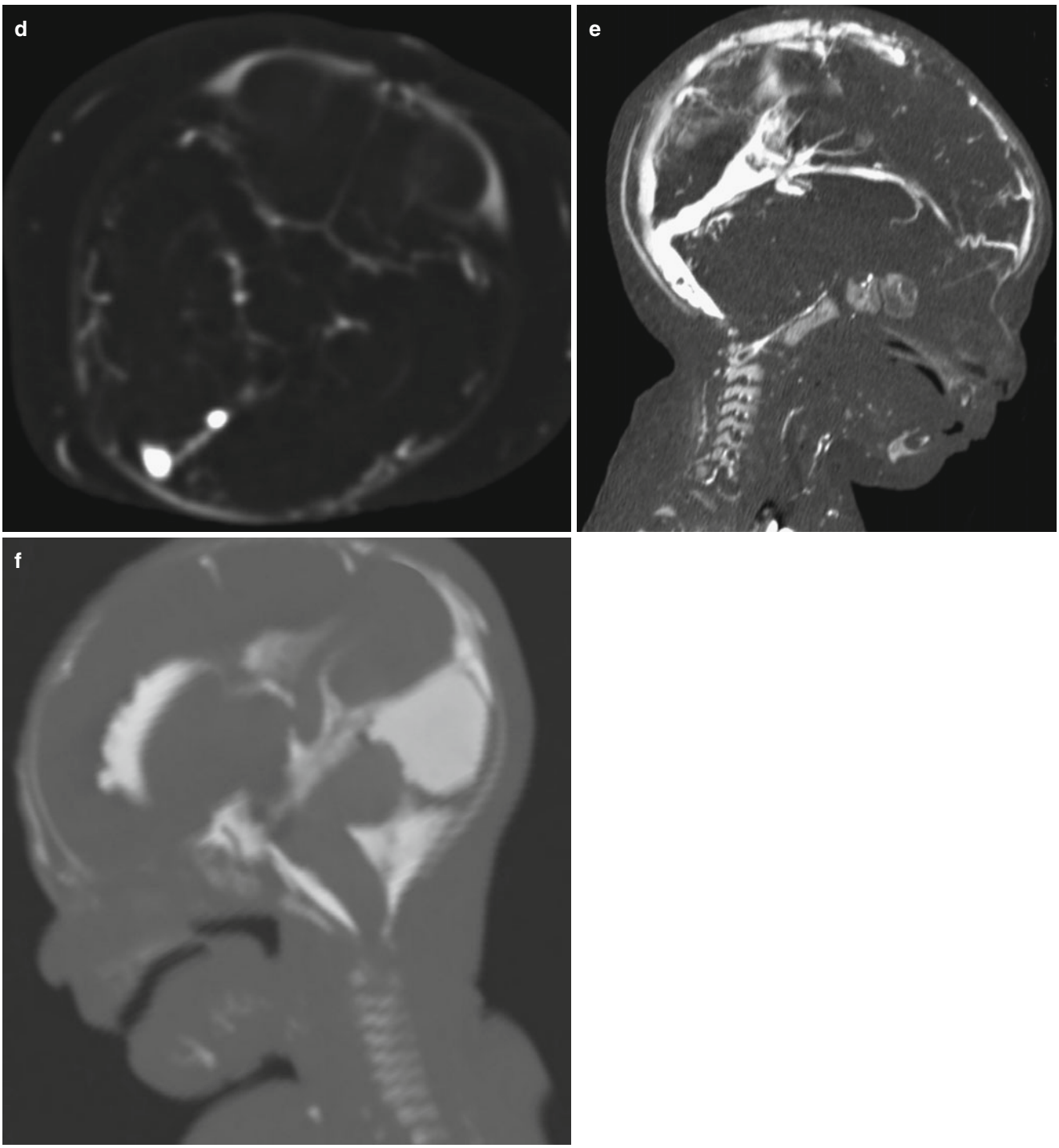

Fig. 7.3 (continued)

7.3 Postmortem CT Angiography Using PEG as Contrast Agent Dissolver

7.3.1 Actual State of the Method

With the goal of enhancing PMCT by contrast agents, new research started focusing on a combination of postmortem angiography with PMCT. The first systematic research in this field was started in 2004 at the Institute of Legal Medicine in Bern, Switzerland in the context of the Virtopsy project. In 2005, Jackowski and colleagues [11] reported preliminary results of a new technique of minimally invasive whole body PMCTA using a cannulation of the femoral vessels on one side of the body and the injection of meglumine ioxithalamate as a contrast agent. At the same time at the Institute, the first experiments were begun with a dynamic angiographic analysis of the whole body using oily liquids [4], which was later developed into the method of "two-step postmortem angiography" [12]. This technique was also the first that used a modified heart–lung machine as a perfusion device. Although Grabherr and coworkers further developed the oily perfusion methods, resulting finally in the technique of multiphase PMCTA [13] (see Chap. 10), other members of the Virtopsy team continued their research based on aqueous solutions. However, they added a modified heart–lung machine as proposed by Grabherr [12] to their technique. Jackowski and associates quickly noticed that the aqueous solutions they used caused tissue edema and artefacts in histologic investigations, which rendered their application in medico-legal cases difficult. Therefore, they sought to overcome these problems and for this reason later proposed adding a hydroscopic PEG as a contrast agent dissolver [5, 14].

Today, a few studies with small numbers of human and animal corpses or organs have shown the possible use of contrast agents in watery solutions and PEG [5, 11]. This mixture is reported to lead to a tissue enhancement that seems to increase the diagnostic value of the method, while higher-viscosity PEG solutions tend to limit extravasation and over-enhancement of various tissues. Doubts remain regarding histologic and biochemical alteration in tissues containing lipid components because PEG acts as a solvent for lipids. However, to date, the number of cases examined in those studies has been too small to provide sufficient information for a thorough assessment of the method. Ross [3] compared mixtures of oily contrast agent and paraffin to water-soluble contrast agent in PEG solutions in ten human cadavers. Although both contrast agents delivered comparable opacification of the vascular system, the hydrophilic contrast agent displayed a pronounced soft tissue enhancement comparable to that reported by Jackowski [5]. The lipophilic mixture showed extravasation in the intestinal tract, an artefact described by Bruguier [15] as well as in Chap. 19. However, it must be noted that the oily mixture used by Ross [3] for this comparison has never been applied in any other study of human bodies. In fact, its viscosity was lower than that normally used in modern PMCTA; therefore the comparison must be viewed with caution. In this study, some artefacts were encountered that could not be fully explained (e.g., overenhancement of neck muscles after failed resuscitation). To date, the number of cases studied with this technique seems too small to fully appreciate any advantages or disadvantages of the method.

7.3.2 Properties of PEG and Water-Soluble Iodinated Contrast Medium

PEG is used as a carrier substance and is made of large polymerized molecules to stay within the vessel lumen so that it does not diffuse into the extravascular system and cause edematization of surrounding tissues.

The water-soluble contrast medium used with PEG is made of unpolymerized smaller iodinated molecules. The different water-soluble iodinated contrast media regularly applied in clinical angiography can be used without any particular differences in postmortem angiography [5].

The mixture of PEG and water-soluble contrast medium is usually in a 10:1 ratio [3]. With a mixture of aqueous contrast agent and PEG, it has to be considered that the resulting perfusion liquid is a hyperosmolar solution, leading to an inflow of water inside a vessel lumen filled with this mixture [16]. For this reason, the surrounding tissue is often desiccated, which can lead to artefacts in histology. Additionally, if the vessel contains remaining blood, the blood can form clots that could be interpreted as thrombi. These aspects may be the reason why this contrast agent mixture did not ultimately take hold as routine in medico-legal cases, especially if PMCTA is to be followed by conventional autopsy. In addition, the quantification of blood loss by measuring blood volume (e.g., in the abdomen) during autopsy is no longer possible because the contrast agent mixture combines with such collections of blood.

7.3.3 Injection Protocol

The institutes using this contrast mixture describe the following injection protocol: an arterial phase of the whole body (length depending on the MDCT abilities) with millimetric acquisition slices after the injection of 1500 mL of contrast media mixture at an injection flow of 600 mL/min. After a pause of 15–20 min, allowing the water-soluble contrast media to diffuse out of the vascular bed, the venous phase is conducted with the same scanning protocol as the arterial phase, at the end of the injection of 1800 mL of contrast media mixture at the same flow rate of injection as previously described.

An additional phase can be performed right after the arterial whole body acquisition, dedicated to the cardiac region, with a 400-mL volume of injection in the arterial system. The body is then turned in the prone position to avoid incomplete filling of the anterior aortic root and heart chambers and to achieve optimal filling of the right coronary artery [3].

As an injection device, either a roller pump (usually no more specifications given) or a modified heart–lung machine is used. However, the mixture can also be injected using other perfusion devices such as a Virtangio machine, as reported by Berger [17] and as shown in our examples.

7.3.4 Case Report

7.3.4.1 Case 1: Drowning

This is a case of a young man suspected of drowning found dead in a lake. The PMCTA was performed in the context of a research project. After the injection of 850 mL of PEG combined with 100 mL of Accupaque 300 (Guerbet Laboratories, Villepinte, France) using a Virtangio perfusion device, most of the arterial system can be observed (Fig. 7.4a, b). Coronal (Fig. 7.4a) and sagittal (Fig. 7.4b) MIP reconstructions of the whole body show a good opacification of the arterial system except for the aortic root, where a layering between the contrast agent mixture and remaining blood can be observed, leading to a lack of opacification of the ostium of the right coronary artery (*arrows* in Fig. 7.4d, e). On the axial view of the brain (Fig. 7.4a–c), all cranial arteries are totally opacified, and a slight enhancement of the central gray substance can be seen (*arrow* in Fig. 7.4c). A good enhancement of the renal tissue is also observed (*arrow* in Fig. 7.4f).

In this case, the venous system was injected using the same parameters. Correct opacification was assessed (Fig. 7.5a: coronal MIP reconstruction) for the main veins, and the azygos system (*arrows*) is clearly visible on a sagittal MIP view (Fig. 7.5b) and an axial MIP view (Fig. 7.5c) of the thorax. In the abdomen, all the branches of the liver veins are visible (Fig. 7.5d).

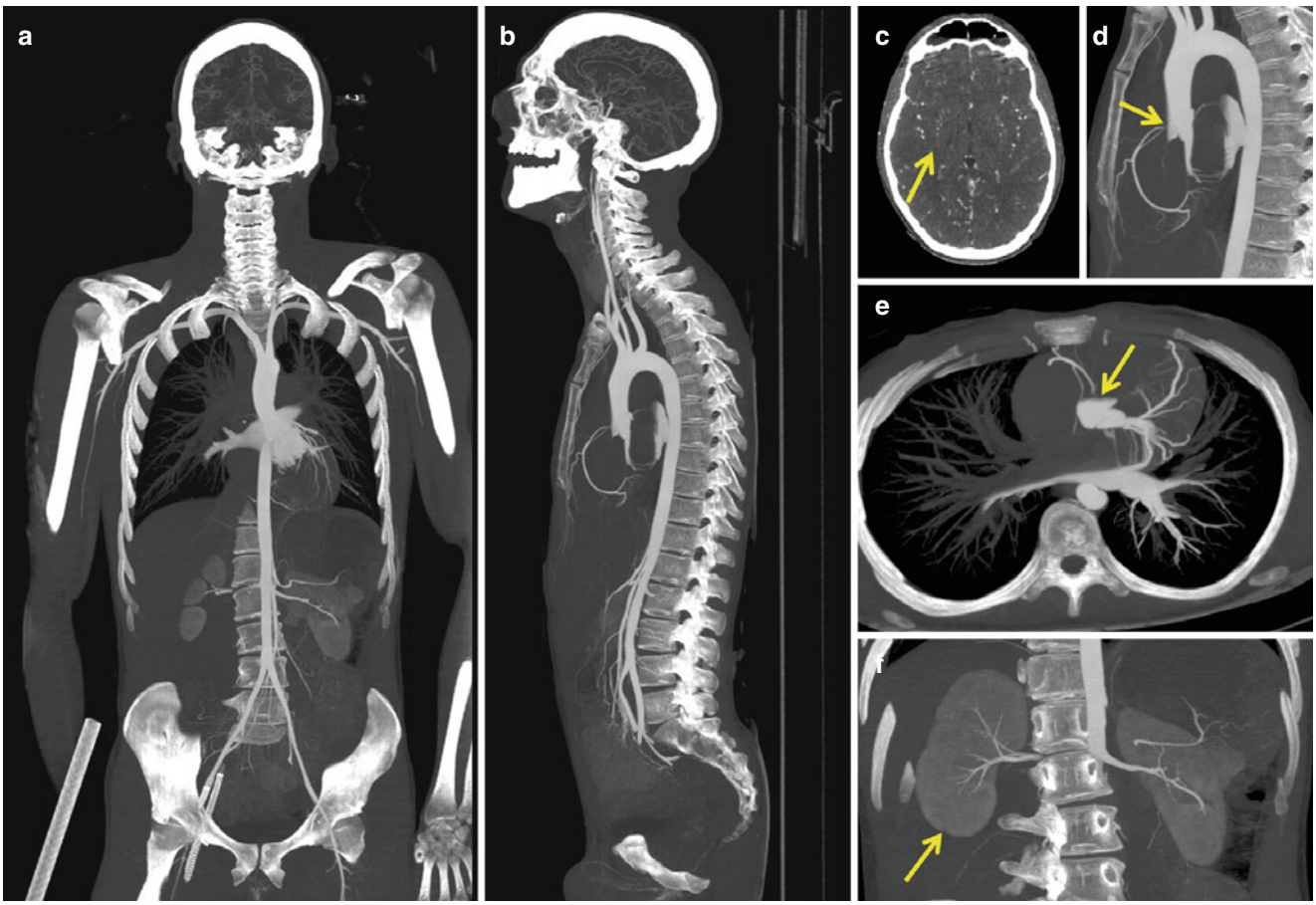

Fig. 7.4 Coronal (**a**) and sagittal (**b**) MIP reconstructions of the whole body. (**c**) On the axial view of the brain, all cranial arteries are totally opacified, and a slight enhancement of the central gray substance can be seen (*arrow*). (**d**, **e**) Lack of opacification of the ostium of the right coronary artery (*arrows*). (**f**) A good enhancement of the renal tissue (*arrow*)

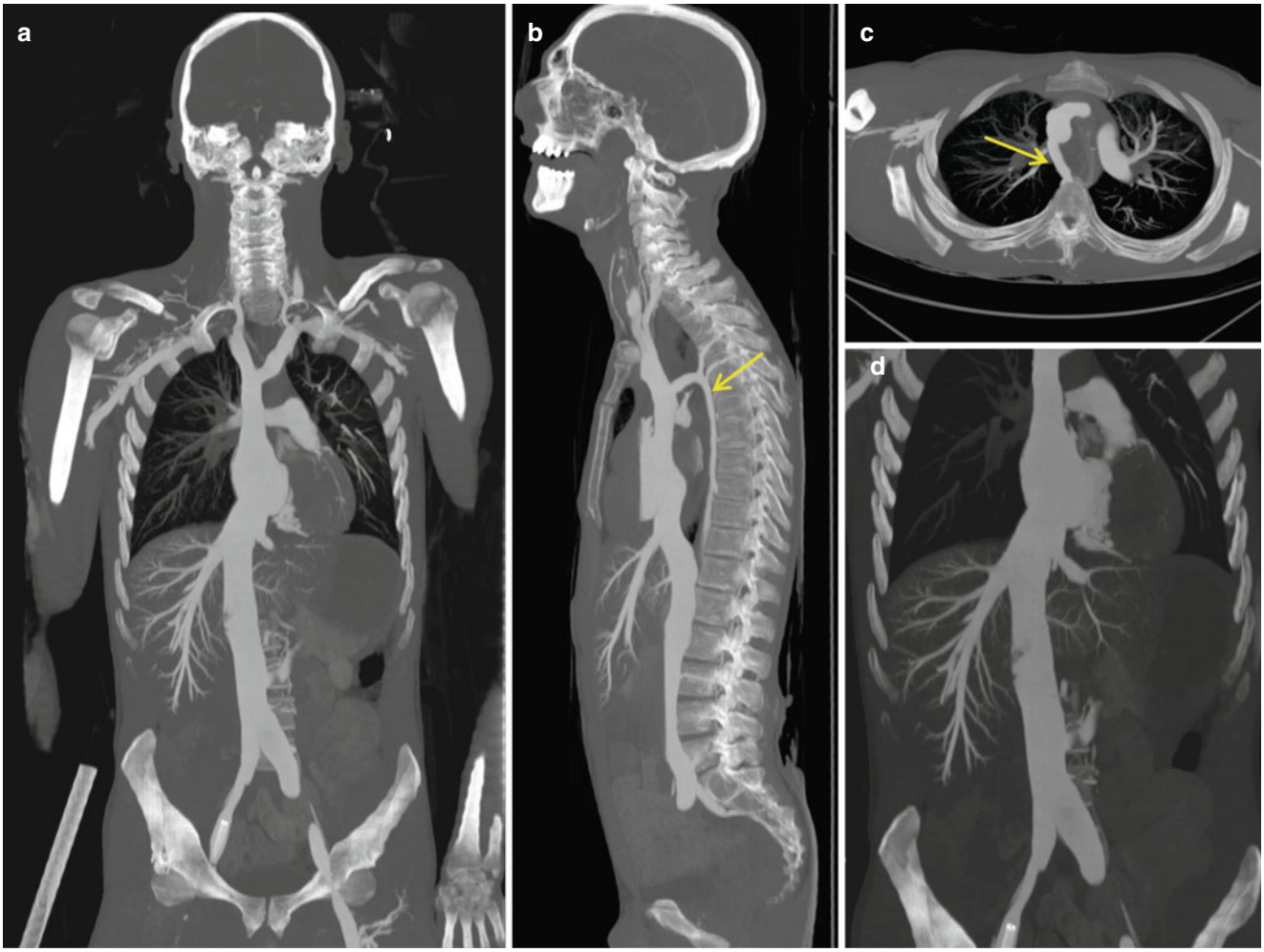

Fig. 7.5 Correct opacification was assessed (**a**) for the main veins. (**b**) The azygos system (*arrows*) is clearly visible on a sagittal MIP view (**b**) and an axial MIP view (**c**) of the thorax. (**d**) In the abdomen, all the branches of the liver veins are visible

7.3.4.2 Case 2: Unexpected Death with Toxicologic Background (THC)

This case was that of a young man with a known history of multiple drug abuse, including cocaine and heroin, who was found dead at home. The PMCTA was performed in the context of a research project, in this case using the same parameters, contrast agent, and perfusion device as in Case 1. Again, a good opacification of all main arteries (Fig. 7.6a, b) can be seen after the first arterial injection, with the same artefact of layering in the aortic root as described in Case 1. All cranial arteries are well perfused, with a good differentiation of the gray and white matter (*arrow* in Fig. 7.6c) and a clear opacification of the circle of Willis (Fig. 7.6d). The left coronary artery can be followed all the way (branches visible in (Fig. 7.6e–g), as can the left mammary artery (Fig. 7.6e–g, *arrow*)).

After the venous injection, opacification of all main veins can be observed (Fig. 7.7a, b). The pulmonary trunk is opacified, including its distal branches (Fig. 7.7c), with the presence of a filling defect resulting from a pulmonary embolism or a postmortem clot in a left lower branch (*arrow*). The liver parenchyma is enhanced nonhomogeneously (Fig. 7.7d), which has to be considered as an artefact. In this case, the filling defect turned out to be a postmortem blood clot at autopsy.

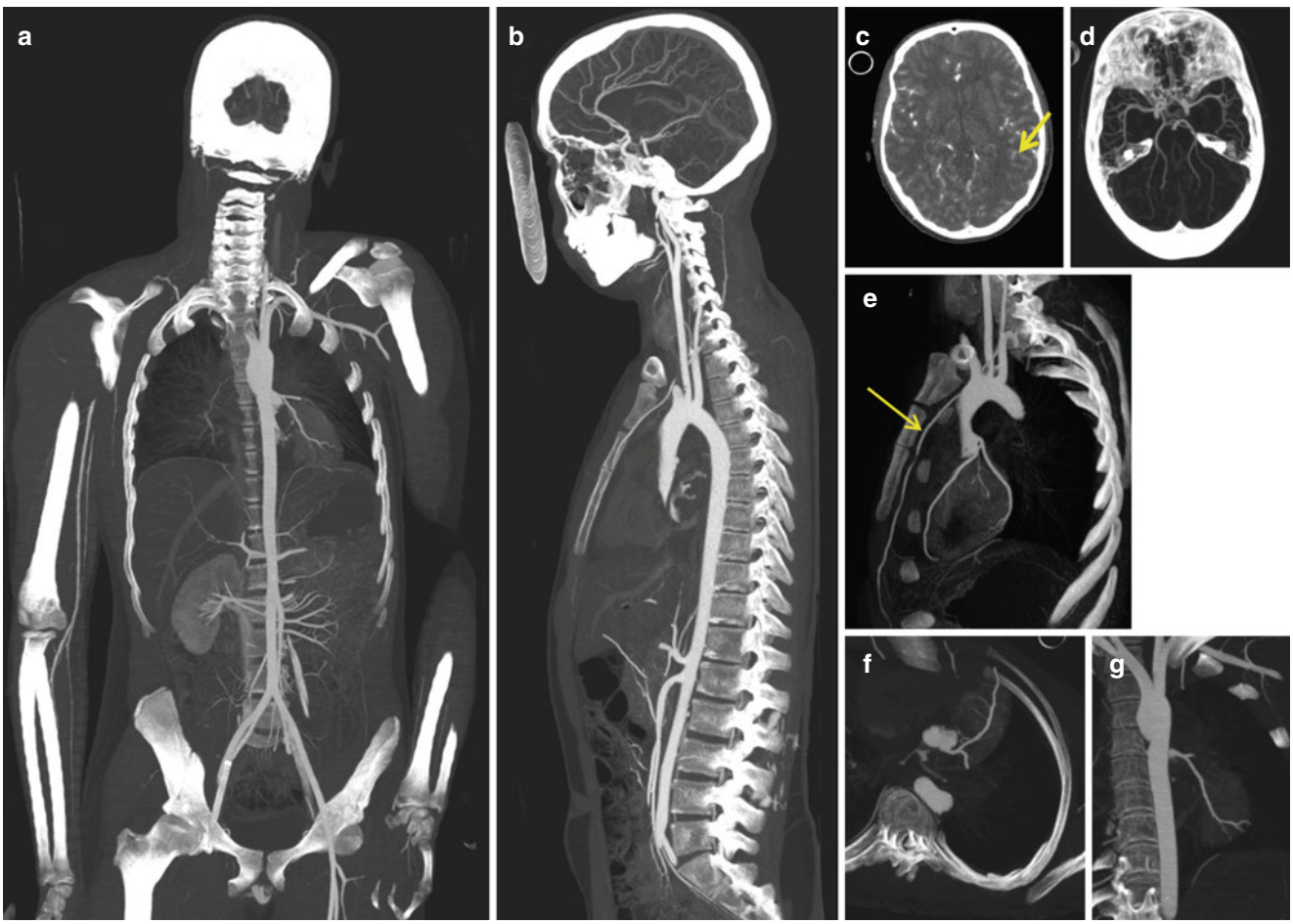

Fig. 7.6 (**a**, **b**) Good opacification of all main arteries. (**c**) Good differentiation of the gray and white matter (*arrow*). (**d**) Clear opacification of the circle of Willis. (**e**–**g**) The left coronary artery can be followed all the way, as can the left mammary artery (*arrow*)

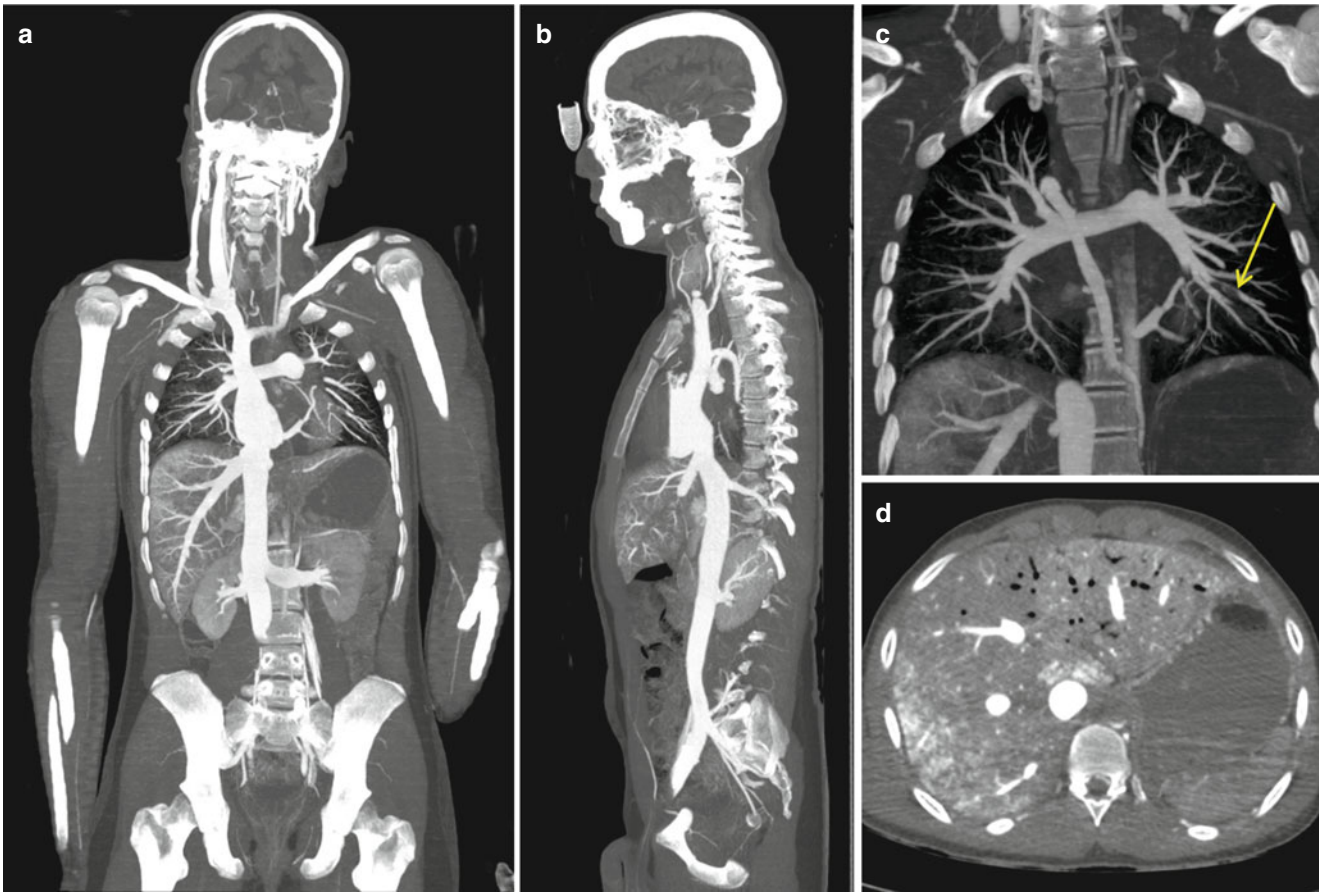

Fig. 7.7 (**a**, **b**) After venous injection, opacification of all main veins can be observed. (**c**) The pulmonary trunk is opacified, including its distal branches, with the presence of a filling defect resulting from a pulmonary embolism or a postmortem clot in a left lower branch (*arrow*). (**d**) The liver parenchyma is enhanced nonhomogeneously

References

1. Beauthier JP. Traité de médecine légale [Legal medicine]. Brussels: Édition De Boeck; 2007.
2. Dirnhofer R, Jackowski C, Vock P, Potter K, Thali MJ. VIRTOPSY: minimally invasive, imaging-guided virtual autopsy. Radiographics. 2006;26:1305–33.
3. Ross S, Spendlove D, Bolliger S, Christe A, Oesterhelweg L, Grabherr S, et al. Postmortem whole-body CT angiography: evaluation of two contrast media solutions. Am J Roentgenol. 2008;190:1380–9.
4. Grabherr S, Djonov V, Friess A, Thali MJ, Ranner G, Vock P, Dirnhofer R. Postmortem angiography after vascular perfusion with diesel oil and a lipophilic contrast agent. Am J Roentgenol. 2006;187:W515–23.
5. Jackowski C, Bolliger S, Aghayev E, Christe A, Kilchoer T, Aebi B, et al. Reduction of postmortem angiography-induced tissue edema by using polyethylene glycol as a contrast agent dissolver. J Forensic Sci. 2006;51:1134–7.
6. Votino C, Cannie M, Segers V, Dobrescu O, Dessy H, Gallo V, et al. Virtual autopsy by computed tomographic angiography of the fetal heart: a feasibility study. Ultrasound Obstet Gynecol. 2012;39:679–84.
7. Kulenović A, Dilberović F. Changes in blood vessels in fetuses 4 to 9 months intrauterine life old by postmortem angiography method. Bosn J Basic Med Sci. 2004;4:50–4.
8. Jolibert M, Cohen F, Bartoli C, Boval C, Vidal V, Gaubert JY, et al. Postmortem CT-angiography: feasibility of US-guided vascular access. J Radiol. 2011;92:446–9.
9. Sarda-Quarello L, Bartoli C, Laurent PE, Torrents J, Piercecchi-Marti MD, Sigaudy S, et al. Whole-body perinatal postmortem CT angiography. Diagn Interv Imaging. 2016;97(1):121–4. doi:10.1016/j.diii.2014.11.002.
10. Sarda-Quarello L, Tuchtan L, Torrents J, Piercecchi-Marti MD, Bartoli C, Laurent PE, et al. Perinatal death: is there a place for postmortem angio-CT? J Forensic Radiol Imag. 2015;3:1–4.
11. Jackowski C, Thali MJ, Sonnenschein M, Aghayev E, von Allmen G, Yen K, et al. Virtopsy: postmortem minimally invasive angiography using cross section techniques—implementation and preliminary results. J Forensic Sci. 2005;50:1175–86.
12. Grabherr S, Gygax E, Sollberger B, Ross S, Oesterhelweg L, Bolliger S, et al. Two-step postmortem angiography with a modified heart-lung machine: preliminary results. Am J Roentgenol. 2008;190:345–51.
13. Grabherr S, Doenz F, Steger B, Dirnhofer R, Dominguez A, Sollberger B, et al. Multi-phase postmortem CT-angiography. Development of a standardized protocol. Int J Legal Med. 2011;125:791–802.
14. Jackowski C, Persson A, Thali MJ. Whole body postmortem angiography with a high viscosity contrast agent solution using polyethylene glycol as contrast agent dissolver. J Forensic Sci. 2008;53:465–8.
15. Bruguier C, Mosimann PJ, Vaucher P, Uske A, Doenz F, Jackowski C, et al. Multi-phase postmortem CT angiography: recognizing technique-related artefacts and pitfalls. Int J Legal Med. 2013;127:639–52. Epub 2013 Mar 21.
16. Grabherr S, Grimm J, Baumann P, Mangin P. Application of contrast media in postmortem imaging (CT and MRI). Radiol Med. 2015;120(9):824–34.
17. Berger N, Martinez R, Winklhofer S, Flach PM, Ross S, Ampanozi G, et al. Pitfalls in postmortem CT-angiography—intravascular contrast induces postmortem pericardial effusion. Leg Med. 2013;15:315–7.