Accepted Manuscript

Usefulness of triphasic CT aortic angiography in acute and surveillance: our experience in the assessment of acute aortic dissection and endoleak

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PII: S1743-9191(16)30134-0

DOI: 10.1016/j.ijsu.2016.05.048

Reference: IJSU 2816

To appear in: *International Journal of Surgery*

Please cite this article as: Reginelli A, Capasso R, Ciccone V, Croce M, Di Grezia G, Carbone M, Maggialetti N, Barile A, Fonio P, Scialpi M, Brunese L, Usefulness of triphasic CT aortic angiography in acute and surveillance: our experience in the assessment of acute aortic dissection and endoleak, *International Journal of Surgery* (2016), doi: 10.1016/j.ijsu.2016.05.048.

Usefulness of triphasic CT aortic angiography in acute and surveillance: our experience in the assessment of acute aortic dissection and endoleak.

Running title: triphasic CT angiography evaluation of acute aortic dissections and endoleaks.

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ABSTRACT

Introduction

Computed tomography angiography (CTA) has been widely used in the diagnostic evaluation of many aortic diseases, but no standardized techniques actually exist for aortic CTA. The aim of this study was to describe the usefulness of triphasic CTA in aortic assessment in both non-traumatic emergency and surveillance conditions.

Methods

We performed non ECG-gated CTA examinations with a 64-slice CT scanner using a triphasic protocol consisting of an unenhanced acquisition, and two (early and delayed) contrastographic phases with a delay of 25-30 seconds and 100-120 seconds respectively after the injection of contrast medium. Were retrospectively selected adult patients with imaging findings of acute aortic dissection (AAD) or endoleak (EL) from November 2012 to November 2014.

Results

AAD was detected in 36 (67%) patients: 23 type A-AADs , and 13 type B-AADs. The presence of EL was observed in 18 (33%) patients: 1 type Ia, 5 types IIa, 2 types IIb, 1 type IIIa and 9 types IIIb.

Discussion

Triphasic CTA is useful to provide correct and prompt diagnosis of AAD in emergency, allowing the evaluation of type and atypical forms of AAD, and the identification of possible branch-vessel involvement and complications. During surveillance, triphasic CTA assures accurate and complete assessment of all known and unknown ELs and it is essential for first follow-up examination.

Conclusion

Triphasic CTA represents a reliable imaging tool for aortic assessment in both non-traumatic emergency and surveillance after endovascular aneurysm repair. Modified protocol could be employed in selected patients and tailored in their known disease.

KEY-WORDS

computed tomography angiography (CTA); triphasic CTA; acute aortic dissection; endoleaks; EVAR

Highlights

- No standardized techniques actually exist for aortic CTA
- Triphasic CTA is useful to provide correct and prompt diagnosis of AAD in emergency
- Triphasic CTA is essential for first follow-up examination during surveillance

ABBREVIATIONS

AA: aortic aneurysm

AAD: acute aortic dissection

CM: contrast medium

CTA: computed tomography angiography

EL: endoleaks

EVAR: endovascular aneurysm repair

HU: Hounsfield Unit

MIP: maximum-intensity projection

MPR: multiplanar reformation

SSD: shaded-surface display

1. Introduction

Over the last two decades, computed tomography angiography (CTA) has been widely used in the diagnostic evaluation of many acute vascular diseases, and this technique currently represents the first line modality in the early diagnosis of abdominal aortic aneurysm (AA), acute aortic dissection (AAD) and pulmonary embolism [1,2]. CTA is also commonly used to follow-up patients treated with endovascular stents and stent grafts with the aim of assessing stent graft patency and stent graft-related complications [1,3].

Actually, no standardized techniques exist for aortic CTA, therefore practices, the type of scanners and acquisition protocols, contrast medium (CM) concentration and administered doses, delay times for contrastographic phases may vary from institution to institution [1,4,5]. Our hospital generally employs a triphasic protocol consisting of an unenhanced acquisition, and two (early and delayed) contrastographic phases. This protocol is chosen both when acute aortic syndrome is suspected and also when patients need to be followed-up to assess any endoleaks (ELs) after endovascular aneurysm repair (EVAR).

The aim of the current study was to describe the usefulness of triphasic CTA in aortic non-traumatic emergency and surveillance conditions presenting our center experience in diagnosing AAD and in assessing post-EVAR EL.

2. Materials and methods

2.1 Study population

This was a retrospective observational study conducted at a single university medical center and approved by our institutional review board. All triphasic CTA examinations performed at our institution from November 2012 to November 2014 were retrospectively reviewed in order to identify and select adult patients with AAD or post-EVAR EL imaging findings.

Our institutional database was checked to retrieve necessary and useful clinical information, such as the time of symptoms onset for patients admitted to our emergency department and the date of

endograft repair or the time when EL was diagnosed for patients who underwent CTA EVAR follow-up.

2.2 CTA protocol and imagine analysis

Non ECG-gated CTA examinations were performed with a 64-slice CT scanner (GE Medical Systems, Milwaukee, WI) scanning from the lung apices to the pelvis before and after intravenous injection of CM, with respiration suspended whenever possible. After a scout view was obtained, initial unenhanced images were acquired. According to patient weight, 90-130 mL of 350 mg iodine/mL (Iomeron 350, Bracco) non-ionic CM were injected into a peripheral vein at a rate of 3-4 mL/sec followed by a saline flush through a double-piston power injector. After unenhanced scanning, an early contrast-enhanced phase was acquired with automatic triggering settled at 100 Hounsfield Unit (HU) or with a delay of 25-30 seconds following CM administration. Then, a delayed contrast-enhanced phase was obtained at 100-120 seconds after CM injection.

Images were initially assessed in axial view and further elaborating multiplanar reformation (MPR) images in sagittal, coronal, oblique sagittal, and curved projections, maximum-intensity projection (MIP) and shaded-surface display (SSD) reconstruction generated on CT scan vendor workstation. According to the Stanford classification, acute type A dissection was defined as any dissection that involved the ascending aorta and/or aortic arch and acute type B as that involving the descending aorta (without any tear in or involvement of the ascending aorta) presenting within 14 days of symptom onset [6,7]. ELs were defined as leakage of CM outside the graft, but within the aneurysm sac and were classified into five types depending upon the origin of the leak (Table I) [8–10] .

3. Results

There were a total of 54 patients (37 Males, 17 Females; 43-78 years, mean age 61 years) included in the study (Table II). CTA examinations performed at our emergency department revealed AAD in 36 (67%) patients: 23 cases of type A-AAD, and 13 cases of type B-AAD. CTA follow-up

examinations showed the presence of EL in 18 (33%) patients: type Ia in 1 case, type IIa in 5 cases, type IIb in 2 cases, type IIIa in 1 case and type IIIb in 9 cases.

Patients with AAD were referred to our institution from 1 to 11 days (mean 3 days) after abrupt-onset pain, defined as sudden severe tearing pain in the chest, neck, or back, or any pain and severe symptoms that brought the patient to medical attention. ELs were assessed from 10 to 82 months (mean 46 months) after aneurysm repair performed at multiple hospitals; the date of endograft repair was not available in 5 patients, although, based on patient history, these patients had grafts placed more than 1 year before referral to our institution. ELs were already known in 6 patients and were newly diagnosed in the remaining 12 cases.

4. Discussion

4.1 Triphasic CTA in acute (non-traumatic) aortic disease

CTA is the practical test of choice in most settings and represents the most commonly used imaging technique for evaluation of suspected acute aortic syndrome and AAD in particular. The identification of an intimal flap and a true and a false aortic lumen are definitive signs of aortic dissection, which allow CTA to diagnose AAD with high sensitivity and specificity [7,11,12]. CM injection rates and technical parameters may vary based on institutional preferences and patients' characteristics, different CT vendors and configuration of scanners. However, protocols for assessing AAD have to include both unenhanced and contrast-enhanced image acquisitions, scanning of the entire aorta from the proximal arch vessels to the common iliac arteries distally, and appropriate optimization of aortic true lumen enhancement [3]. All of these necessary features are part of our institutional CTA protocol.

The primary role of unenhanced scanning is to detect medially displaced aortic calcifications [3]. The unenhanced images may also be helpful to assess high attenuation within the aortic wall resulting from either a hyperdense false lumen or the presence of intramural hematoma [3,13–15]. Furthermore, it is reported that unenhanced CT could directly show the intimal flap of the

dissection, especially in patients with severe anemia [16]. If the contrast between the density of the aortic wall and the density of the aortic lumen is large, the intimal flap of AAD appears visible on unenhanced CT (Figure 1) [3,11]. In patients with adverse reaction to iodinated CM or with impaired renal function, these findings may be sufficient for diagnosis or for serial monitoring without administration of potentially nephrotoxic iodinated intravenous CM [3]. Unenhanced CT is also useful to appreciate signs of aortic rupture revealing hyperattenuating mediastinal, pericardial, or pleural fluid collection [13].

The administration of intravenous CM is essential to appreciate the diagnostic key finding of AAD and an intimal flap separating the true lumen from the false lumen [3,7]. An appropriate scan delay is critical for accurate vascular imaging [17]. As a general rule, a standard delay of 25 seconds for multi-detector CTA will usually suffice. One may perform a test injection to determine the time to optimal aortic opacification in a given patient. A 20-cc bolus of contrast is administered and after 10 seconds, one image every 2 seconds is acquired at the same level for a total of 30 seconds. The image with the greatest contrast density is used to select the proper scan delay. This method is somewhat cumbersome to perform routinely, and has the added detraction of an increased radiation dose as well as a slight increase in visceral background attenuation due to the injected contrast [4]. As an alternative, bolus timing software packages allow the time to peak enhancement to be monitored without a separate test injection. These programs monitor the attenuation within a region of interest (ROI) drawn within the vessel in question and display the attenuation graphically in real-time during the contrast injection. Once the graph demonstrates a sharp rise in attenuation, the scan sequence is triggered automatically according to the HU threshold value settled or started manually according visual assessment of lumen opacification [4]. At our institution, we prefer to use bolus timing software with automatic triggering settled at 100 HU positioning a ROI within the ventral side of distal thoracic aorta. Manual starter is reserved for cases of automatic trigger failure. In the present study, manual starter was employed in 2 cases and was respectively due to inadequate positioning of the ROI slightly outside the vessel lumen (probably patient moved during CM

injection), and to an atypical course of the true lumen (Figure 2).

CM administration is required to provide information regarding the type and the extent of AAD, the status of false lumen, and blood flow in aortic branches [11,18]. The false lumen usually has slower flow and a larger diameter. The differentiation between false and true lumen can sometimes be challenging, especially when both lumens appear similar in degree of opacification and size [3,7,18]. In some cases, the intimal flap has an atypical configuration such as: dissection of the entire intima with a circumferential intimal flap, a filiform true lumen, a calcified false lumen in chronic dissection, a three-channel aorta (Mercedes-Benz sign) or an aorta with several false channels; and intima-intimal intussusception [7,12]. In our study 1 case of circumferential intimal flap was observed (Figure 3). Accurate differentiation at CT between the true and the false lumen was relatively unimportant previously because surgery was the main therapy used; however, this distinction recently has become particularly important for planning endovascular treatment of dissection because the endograft must be positioned in the true lumen [19,20]. Both approaches require accurate localization of the intimal tear site because both open surgical repair and stent-graft implantation usually attempt to occlude the tear and to induce thrombosis of the false lumen [21,22]. In this context, MIP, MPR and SSD images reconstruction (Figures 4,5) are an indispensable tool which allows multidetecor CTA to provide specific and precise measurements of anterograde or retrograde extent of dissection, including length, diameter of the aorta and the true and false lumens, involvement of vital vasculature, and distance from the intimal tear to the vital vascular branches [3,7].

More than one-third of patients with aortic dissection present signs and symptoms secondary to other organ system involvement. The most common mechanism is the development of ischemia secondary to obstruction of branch arteries originating from the aorta. There are two principal mechanisms of branch-vessel compromise: static, if the dissection flap intersects or enters the branch-vessel origin and dynamic, if the intimal flap spares the branch vessel but prolapses and

covers the branch-vessel origin like a curtain. A branch-vessel obstruction could also be caused by a direct compression of the branch artery by an expanding false lumen. Another mechanism of organ system involvement is rupture of the dissected aorta, causing blood to leak into the surrounding structures. Such events are usually fatal. It is therefore important to evaluate the entire aorta so as to determine the distal extent of the dissection and to detect possible abdominal ischemic disease that might increase morbidity and mortality [7,23]. In order to identify any parenchymal areas of hypoperfusion/ischemia, we routinely perform delayed contrastographic phases 90-100 seconds after CM administration. Obstruction in the main abdominal arterial branches (celiac, superior mesenteric, renal, and inferior mesenteric arteries) and parenchymal ischemic injuries can be easily demonstrated with CTA. The diagnosis can be made on transverse CT images, but MPR images play an important complementary role in determining the extent of involvement of aortic branch vessels. Finally, delayed contrastographic phase is also necessary to visualize slow flow in the false lumen, appearing not well enhanced in early contrastographic phase, in order to exclude its complete occlusion or thrombosis. One of our patients presented abdominal symptoms suggestive of acute bowel ischemia and mesenteric occlusion was suspected. On early contrastographic phase, CTA showed a type-B AAD with patent mesenteric arteries while delayed contrastographic phase excluded ischemic bowel injury.

4.2 Triphasic CTA in post-EVAR surveillance

Stent-graft integrity is of paramount importance to EVAR, and this can only be assessed by medical imaging. Currently, CTA is the preferred imaging modality for routine imaging follow-up of postoperative EVAR [1,24,25]. Many patients require reintervention during the middle and long-term follow-up because of procedure-related complications. For this reason, surveillance of these patients is crucial to determine the long-term performance of these devices [9]. Commonly employed CT surveillance protocols recommend regular scans at 1, 6 and 12 months post-implantation and at yearly intervals thereafter. CTA is useful to detect post-procedural complications such as migration,

kinking, structural failure, infection, and EL with aneurysm growth (Figure 6) [25–27]. EL is a common procedural failure due to persistent flow outside the graft within the aneurysm sac causing further enlargement and rupture of the aneurysm sac itself [9,28,29].

CT protocol considered most reliable in detecting complications consists of a triphasic protocol including unenhanced, arterial phase (30-second delay), and delayed (120- to 300-second delay) phases, and it has been preferred for post- EVAR surveillance [8,9,25]. The unenhanced images can be helpful to avoid false-positive diagnoses, distinguishing hyperdense materials from an EL that appears on the arterial and/or delayed phase, but generally absent on image [8,9,25]. Then, unenhanced phase enables differentiation between true ELs and areas of calcification or high attenuation that mimic ELs (pseudo-ELs) [8,25,9]. Because ELs have variable flow rates, they can be detected at variable times after CM administration. For this reason, a delayed phase is recommended to detect ELs not appeared during the earlier arterial phase, the so-called low-flow ELs [9,25]. Assessing the timing at which contrast appears in the aneurysm sac is also important for classification. As in our series, a type I endoleak manifests as early contrast opacification along the stent-graft attachment sites (Figure 7), whereas a type II endoleak may appear on more delayed images, as we observed in 3 patients (Figure 8,9) [25,30,31]. At our institution, the arterial first pass scan is always followed by a delayed scan in order to not overlook slow flow ELs, which might have been missed on the first pass scan [8,25].

In order to reduce radiation dose, routine delayed images may be not always necessary and some authors have suggested employing a biphasic protocol (unenhanced and arterial first pass scans), but others have argued about their reliability in detecting slow flow ELs [8,18]. Others propose that eliminating the arterial phase would lead to reduced radiation exposure and still allow the detection of an EL on delayed images [25]. In past years, researchers in two studies have suggested the same detection sensitivity for biphasic protocols (a non- enhanced phase and a venous phase) compared with triphasic protocols; however, neither of these studies had an external reference standard [24,32,33]. Also the unenhanced scan could be not always needed and reserved

for first surveillance examination while omitted thereafter in the absence of complications [8,25]. Subsequent scans can be performed with a biphasic protocol, and then compared with the initial non-contrast scan, thus minimizing radiation exposure to patients [8].

In our study, as it generally happens at our institution, most (14/18) of the patients were observed for the first time and previous CTA examinations were not always available for a prior evaluation in order to set up a focused CTA scan. Moreover, because the findings of different types of ELs may be very similar on CTA, misclassification should be investigated [34]. Thus, triphasic protocol seemed to be the most reliable protocol for a complete assessment of any post-EVAR complications, depicting also the presence of any incidental extra-vascular findings. The unavailability of previous CTA examinations for a comparison of imaging findings in most patients referred to our institution from several different hospitals, may explains why we did not detect any case of type V EL, whose diagnosis requires the demonstration of a growth of the aneurysm sac without evident reperfusion defects [9]. For each surveillance study, size measurements should be precisely compared with prior measurements. To limit interobserver variability, measurements should be obtained in a plane perpendicular to the aneurysm centerline with fine calipers using the outer aneurysm wall as the boundary (adventitia-to-adventitia) [8]. In order to provide accurate measurements to be compared with previous/successive ones, we generally employ advanced reconstruction techniques, including 2D MPR, curved planar reformations created on lumen center-line, and 3D reconstructions [25].

4.3 Limitations

The present study had several limitations particularly due to its retrospective nature. The most important limitation was the heterogeneity of the study sample and the loss of information regarding patients' outcome because treatment and follow-up were often performed in different institutions. However, our study reflects the real working conditions and needs in the vast majority of hospitals where unselected patients are referred to perform angiographic examinations.

5. Conclusions

When AAD is suspected, triphasic CTA should be the first diagnostic test performed. Multi-phasic examination is required to provide correct and prompt diagnosis, allowing the evaluation of type and atypical forms of AAD, and the identification of possible branch-vessel involvement and complications. During CTA follow-up after EVAR, triphasic protocol is essential for first surveillance examination, thereafter CTA protocol could be modified according to previous imaging findings in order to reduce radiation dose. However, triphasic CTA assures accurate and complete assessment of all known and unknown ELs.

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LEGENDS

TABLE I: There are several causes of endoleak which can be classified into five types as showed in this table, depending upon the origin of the leak.

TABLE II: This table shows the total number (n.) of patients included in the study with acute aortic dissection and endoleak imaging findings; are also reported the number and the percentage of patients for each type of disease.

Figure 1: Unenhanced image shows the intimal flap as a thin hypodense line (white arrows) within aortic lumen.

Figure 2: Manual starter- early contrastographic image reveals the presence of an atypical course of the true lumen which is visible in the posterior side of thoracic aorta, back to the false lumen (F).

Figure 3: Circumferential intimal flap- a) axial image and b) oblique coronal reconstruction show the true lumen (black star) surrounded by false lumen.

Figure 4: Acute aortic dissection type A- a) axial image, b) curved projection and c) shaded-surface display reconstruction allow to assess the course of intimal flap.

Figure 5: Acute aortic dissection type B- a,b) axial images and b) coronal view show the sparing of ascending aorta.

Figure 6: Type IIIa endoleak - a) coronal and b) axial images show contrast medium leak (white arrows) strictly adjacent to a junctional gap between modular components, with little contact with margins of the aneurysmal sac; Type IIIb endoleak - c) coronal and d) axial images show contrast medium leak (black asterisk) near a tear in the graft material without opacification of the lumbar arteries or inferior mesenteric artery.

Figure 7: Type Ia endoleak - a) axial and b) coronal images reveal the leakage of contrast medium from the proximal attachment site; type Ib endoleak - c) axial and d) coronal images reveal the leakage of contrast medium from the distal attachment site.

Figure 8: Type IIb endoleak - a) axial image and b) shaded-surface display reconstruction in early contrasographic phase, depict the leak of contrast agent in a posterolateral location within the aneurysm from the lumbar arteries.

Figure 9: Slow flow type II endoleak- the leakage of contrast medium was appreciable on delayed contrastographic phase only, resulting from retrograde flow into the aneurysm sac from a feeding lumbar vessel (white arrow).

ACKNOWLEDGMENT

This work received no funding. The authors declare that they have no competing interests.

FUNDING

All authors have no source of funding.

COMPETING INTEREST

All authors have no conflict of interests.

AUTHORS' CONTRIBUTION

AR: Partecipated substantially in conception, design, and execution of the study and in the analysis and interpretation of data; also partecipated substantially in the drafting and editing of the manuscript.

RC: Partecipated substantially in conception, design, and execution of the study and in the analysis and interpretation of data; also partecipated substantially in data collection and in the drafting and editing of the manuscript.

VC: participated substantially in data collection, execution of the study and in the analysis and interpretation of data.

MCr: participated substantially in data collection and in the analysis and interpretation of data.

GdG: partecipated in the drafting and editing of the manuscript and critically reviewed the manuscript.

MCa: carried out the imaging examinations, contributed to data collection and imaging analysis, reviewed the manuscript, and approved the final manuscript as submitted.

NM: Partecipated substantially in conception, design, and execution of the study and in the analysis and interpretation of data

AB: Partecipated substantially in conception, design of the study and in the analysis and interpretation of data

PF: critically reviewed the manuscript, made general supervision and approved the final manuscript as submitted

MS: critically reviewed the manuscript, made general supervision and approved the final manuscript as submitted

Alfonso Reginelli and Raffaella Capasso contributed equally to this work.

TABLE I: There are several causes of endoleak which can be classified into five types as showed in this table, depending upon the origin of the leak.

CLASSIFICATION OF ENDOLEAKS
• **type I**: leak at graft attachment attachment site Ia: proximal Ib: distal Ic: iliac occluder
• **type II**: aneurysm sac filling via branch vessel (most common) IIa: single vessel IIb: two vessels or more
• **type III**: leak through defect in graft IIIa: junctional separation of the modular components IIIb: fractures or holes involving the endograft
• **type IV**: leak through graft fabric as a result of graft porosity
• **type V**: continued expansion of aneurysm sac without demonstrable leak on imaging (endotension)

TABLE II: This table shows the total number (n.) of patients included in the study with acute aortic dissection and endoleak imaging findings; are also reported the number and the percentage of patients for each type of disease.

RESULTS						
PATIENTS Total n.	**DIAGNOSIS**	**n.**	**%**	**TYPE**	**n.**	**%**
54	ACUTE AORTIC DISSECTION	36	*67*	A	23	*64*
				B	13	*36*
	ENDOLEAK	18	*33*	IA	1	*5.5*
				IIA	5	*28*
				IIB	2	*11*
				IIIA	1	*5.5*
				IIIB	9	*50*

Figure 1: Unenhanced image shows the intimal flap as a thin hypodense line (white arrows) within aortic lumen.

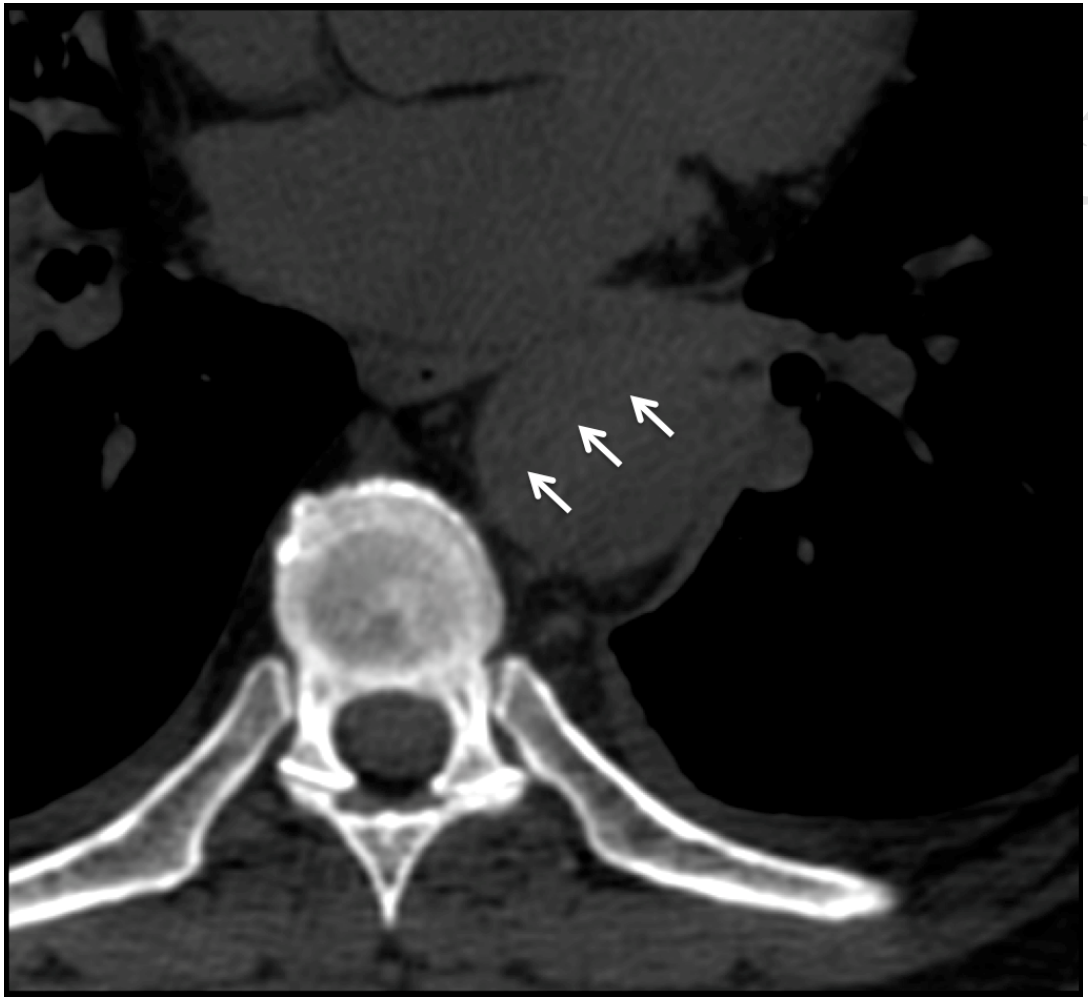


Figure 2: Manual starter- early contrastographic image reveals the presence of an atypical course of the true lumen which is visible in the posterior side of thoracic aorta, back to the false lumen (F).

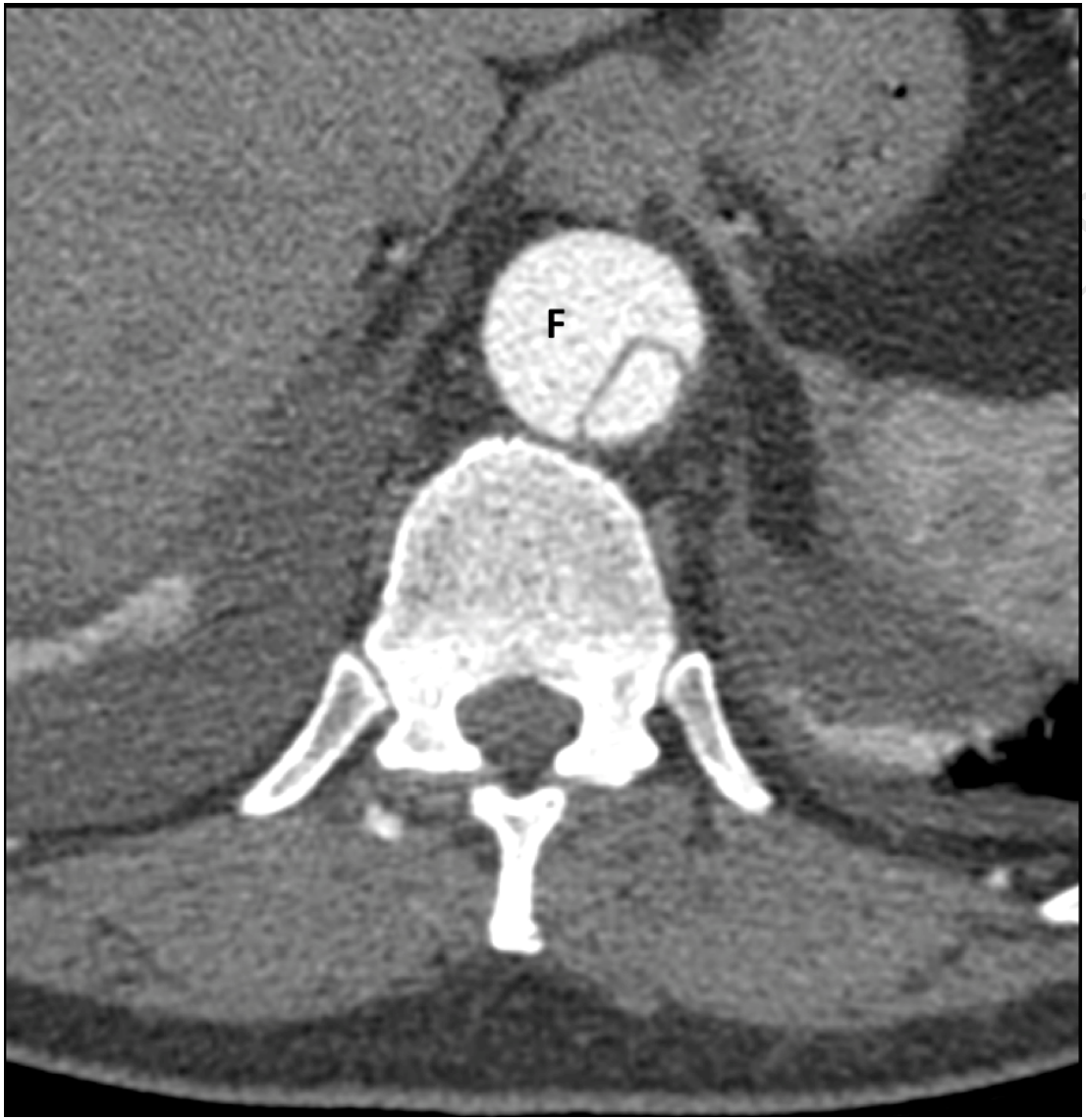


Figure 3: Circumferential intimal flap- a) axial image and b) oblique coronal reconstruction show the true lumen (black star) surrounded by false lumen.

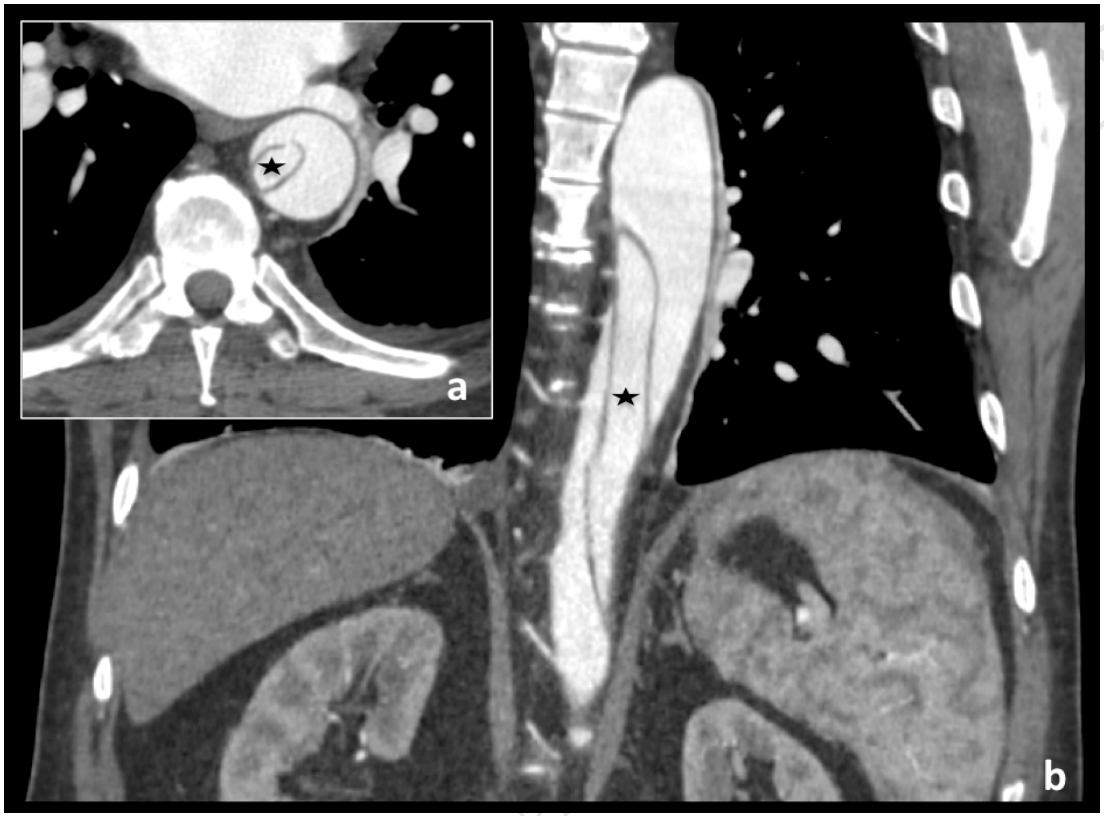


Figure 4: Acute aortic dissection type A- a) axial image, b) curved projection and c) shaded-surface display reconstruction allow to

assess the course of intimal flap.

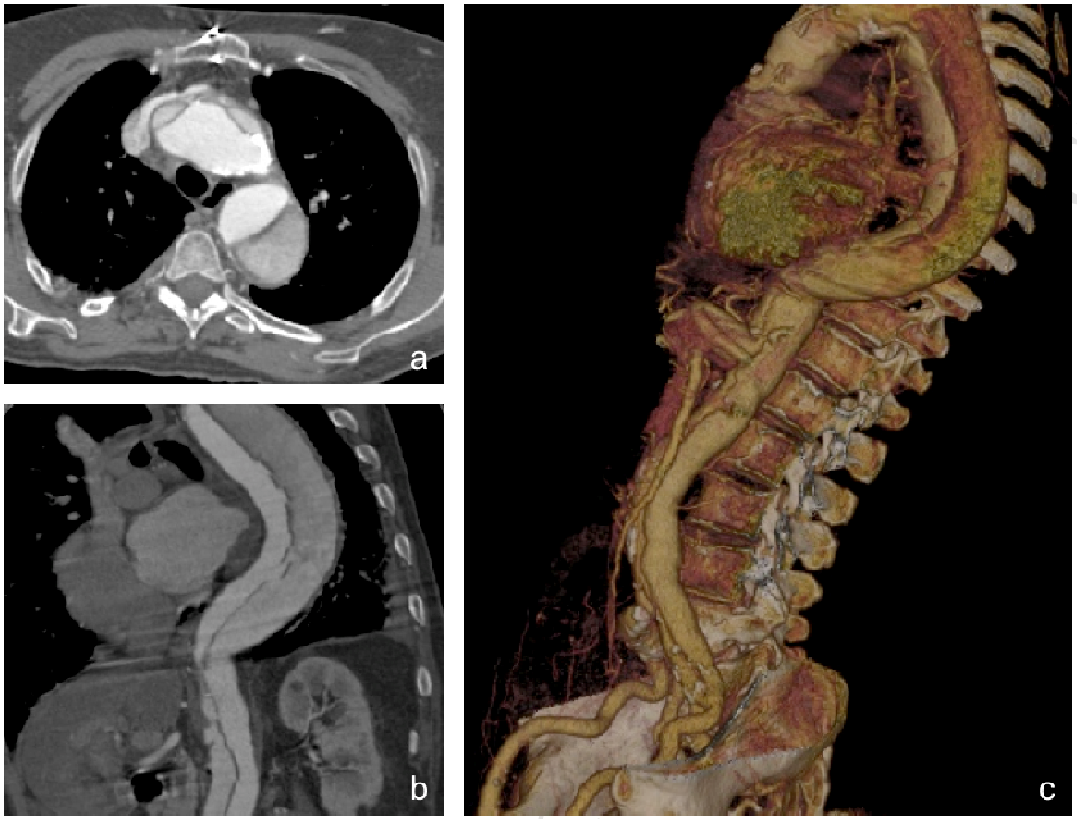


Figure 5: Acute aortic dissection type B- a,b) axial images and b) coronal view show the sparing of ascending aorta.

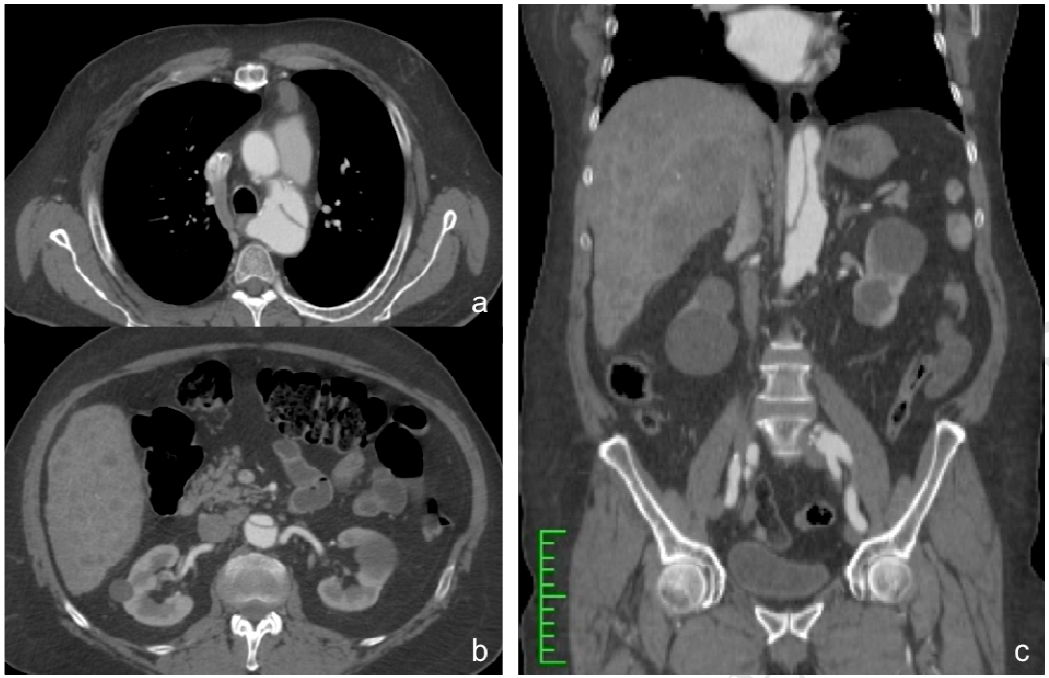
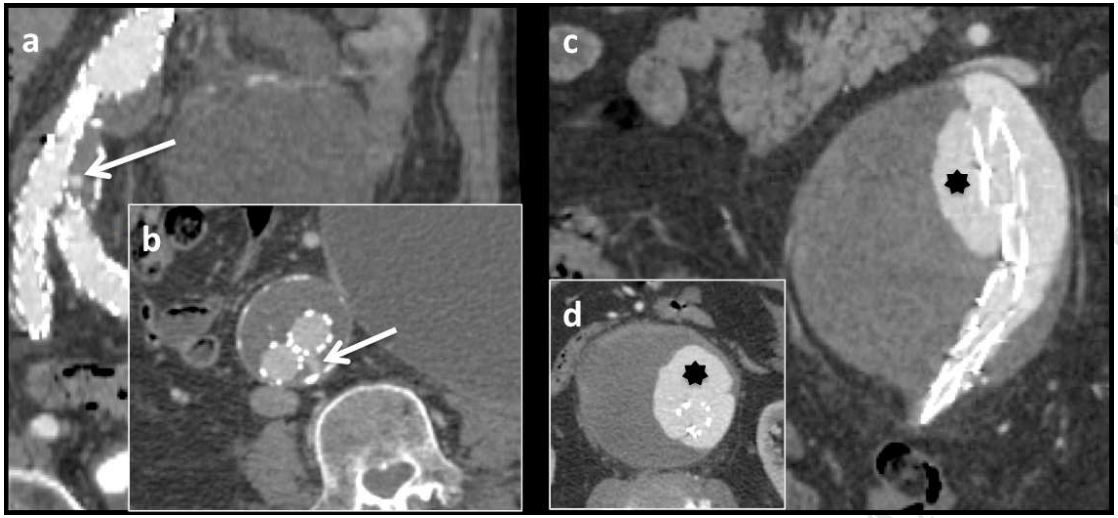


Figure 6: Type IIIa endoleak - a) coronal and b) axial images show contrast medium leak (white arrows) strictly adjacent to a junctional gap between modular components, with little contact with margins of the aneurysmal sac; Type IIIb endoleak - c) coronal and d) axial images show contrast medium leak (black asterisk) near a tear in the graft material without opacification of the lumbar arteries or inferior mesenteric artery.



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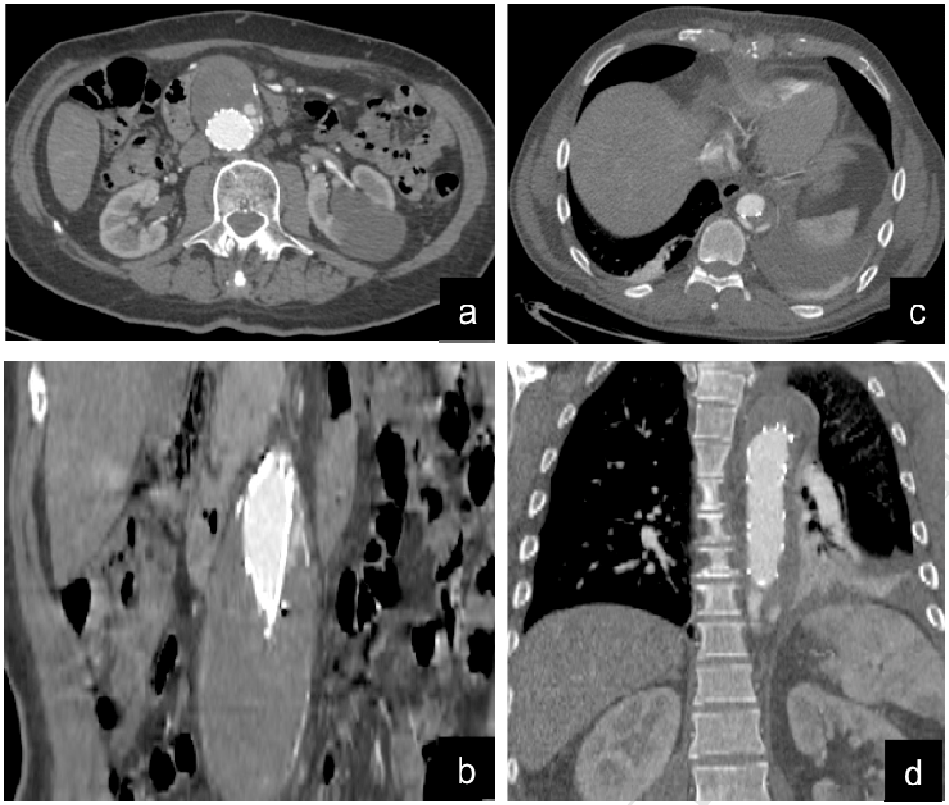
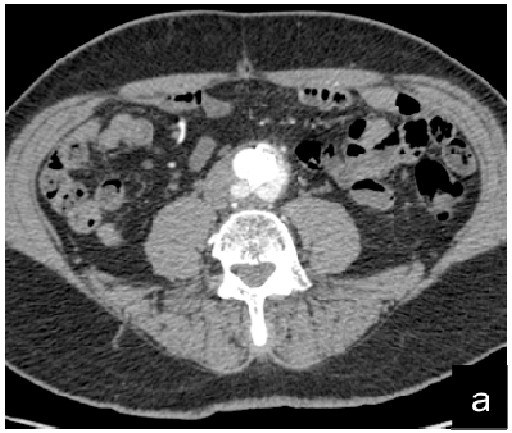
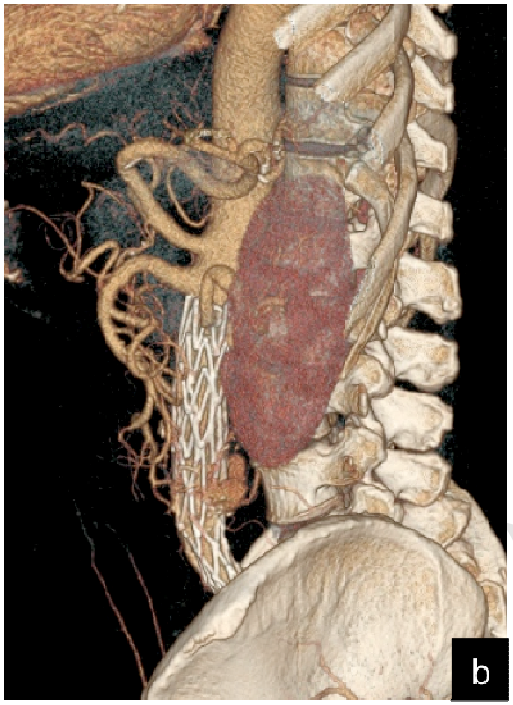


Figure 8: Type IIb endoleak - a) axial image and b) shaded-surface display reconstruction in early contrasographic phase, depict the leak of contrast agent in a posterolateral location within the aneurysm from the lumbar arteries.





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