Comprehensive evaluation of patients suspected with catheter-related thrombosis using indirect CT venography with multi-detector row technology: from protocol to interpretation

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Learning objectives

Early and accurate diagnosis of the catheter-related thrombosis facilitates proper management to alleviate the symptoms and to avoid related complications. Recently, indirect CT venography with multi-detector row technology has become an important noninvasive diagnostic tool in clinical practice. This article will introduce the scanning techniques, interpretation algorithm, and image findings including catheter-related thrombosis and other associated and alternative diagnoses.

Background

For a patient suspected with catheter-related thrombosis (CRT) [1, 2], a fast imaging modality providing accurate diagnosis with high-resolution anatomic evaluation is very helpful. It could be fatal if the CRT-related pulmonary embolism was not diagnosed in time. Also, the inserted catheter, no matter it is pacemaker or chemoport, is very important for the patient's treatment and can't be simply removed for treating CRT. Early and accurate diagnosis of the CRT facilitates proper management to alleviate the symptoms and to prevent from thrombus progression, pulmonary embolism and post-thrombotic syndrome [1].

Recently, high accuracy of indirect CT venography in diagnosing DVT has been proven [3]. Indirect CT venography with multi-detector row technology also replaced sonography, invasive venography and magnetic resonance venography as a standard diagnostic tool, due to its short scan time, wide availability, non-invasiveness, excellent image quality and post-processing capability [3,4]. To the best of our knowledge, no educational article has been published on this topic. This pictorial essay is intended to familiarize radiologists with the techniques and essential knowledge in using MDCT to evaluate patients suspected with CRT.

Imaging findings OR Procedure details

TECHNIQUES

MDCT scan

In our institution, we used a 64-detector-row CT scanner (Brilliance 64, Philips Medical System, Best, The Netherlands) to perform all the scans. Because pulmonary embolism is prevalent in cancer patients [5] and is a potentially fatal complication of catheter-related thrombosis, we performed CT pulmonary angiography with indirect venography (CTVPA) [3] to evaluate patients suspected with catheter-related thrombosis [1].

A 20-gauge intravenous catheter is placed in the arm opposite to the symptomatic upper limb. When positioning the patient, the arm to be examined is placed beside the body, leaving a small gap between the arm and body to avoid venous compression. The opposite arm with the intravenous catheter is then raised above the head to reduce artifacts in the scan region. We suggest this arm-down setting because it is the neutral human body position [6]. In contrary, the arm-up position is associated with patient discomfort and even motion artifacts in the scan, especially for older people or those with joint motion limitation [6].

The scan parameters were based on previous studies [3,4,7]. A total of 2.0 ml/kg of body weight of iohexol (Omnipaque 350; Amersham, Cork, Ireland) and then 30 mL saline bolus were injected with a flow rate of 3.5 mL/s. CT pulmonary angiography was obtained using bolus tracking technique with post-threshold delay set by 'contrast-covering time' concept (ranging from 13 to 25 according to the total contrast volume)[8] with a threshold of 150 HU and a region of interest placed in the main pulmonary artery. Scan parameters are 64*0.625 mm, 120 kVp, 150 mAs/slice with online dose modulation (D-DOM, Philips Healthcare System), pitch of 0.8, rotation time of 0.5 s for whole lung. After 3.5 minutes, indirect CT venography of the involved upper limb is subsequently performed from the upper margin of the shoulder to the end of the fingers. Scan parameters are 64*0.625mm, 120 kVp, tube current upper limit of 180 mAs/slice with online dose modulation (D-DOM) turned on, pitch of 1.02 and rotation time of 0.5 s. The reconstruction thickness/interval was 1.4/0.9 mm[4]. The effective dose of this protocol was 9.8 mSv +- 1.7mSv in our 5-year single institute experience [9].

Interpretation

Due to the complicated venous anatomy, a dedicated MDCT workstation (Extended Brilliance Workspace; Philips, Best, The Netherlands in our institution) is suggested for interpretation. The thin section axial images are loaded into an interactive post-processing viewer (CT Viewer; Extended Brilliance Workspace, Philips) to evaluate the pulmonary arteries, the superficial and deep veins of the symptomatic upper arms and the adjacent anatomic structures to comprehensively evaluate the patient.

Catheter-related thrombosis and associated conditions/complications

Acute catheter-related thrombosis

Acute venous thrombosis is presented as filling defects with low attenuation (30 to 50 HU) [4], venous lumen dilatation, venous wall enhancement and perivenous edema (Fig. 1, 2). In the following, we will introduce the common causes and locations of CRT according to the famous Virchow triad of predisposing factors [4].

Stasis. Due to gravitational stress, femoral venous catheterization is more prone to the formation of CRT than subclavian assess [1,2]. Mechanical obstruction of the catheter such as kinking (Fig. 1**)**, tip directly impinged by vessel wall, or pinch-off syndrome can all lead to blood stasis which further causes thrombus formation. For majority of the patients with CRT, 5-7 days of low-molecular-weight heparin (LMWH) in combination with at least 3 months of vitamin K antagonists (VKA) is effective. Removal of the catheter is only indicated if there is catheter malfunction or infection, if anticoagulation therapy is contraindicated or has failed, or if the catheter is no longer needed. Thrombolytic therapy remains unclear for the treatment of catheter-related thrombosis [1,10].

Hypercoagulability. Malignancy is associated with hypercoagulability state of the patients [11], which further predispose the patient to thrombus formation (Fig. 1, 2). For patients with catheter-related thrombosis with underlying malignancy, treatment strategy for cancer itself in combination with LMWH rather than VKA is suggested as gold standard [10,11].

Vessel wall injury. Most thrombi originate from the point where a catheter enters the vein or at any point where it persistently rubs against the vessel wall, especially in patients with long term indwelling catheter [4,12]. The recommended insertion site of the catheter is over right subclavian vein rather than left, because the left innominate vein forms a more acute angle with the superior vena cava, which causes increased possibility of vessel wall injury when advancing catheter or guidewire [12].

Chronic catheter-related thrombosis

Chronic CRT may occur 2 to 8 weeks after acute CRT. In patients with chronic CRT, the thrombi may be calcified (Fig. 2), and the venous lumen may be shrunk or obliterated (Fig. 3). Collateral veins are established and may present as superficial varicose veins [4]. Anticoagulant and thrombolytic therapy should be tried first. However,Sometimes surgical interventions with removal of the catheter are still sometimes needed for patients who have persistent symptoms after anticoagulant or thrombolytic therapy [1].

Postthrombotic syndrome

Postthrombotic syndrome (PTS) usually occurs within 2 years after episodes of acute venous thrombosis, which is due to damage of the venous valves by thrombus or inflammatory mediators, leading to valvular insufficiency and venous hypertension [1,2,13]. The patients may present as pain, edema, erythema, varicose veins, eczema and even chronic ulcers of the involved limbs. After excluding new or recurrent thrombosis, PTS could be diagnosed clinically in such patients (Fig. 4). According to the 2008 American College of Chest Physicians guideline, elastic bandages or elastic compression sleeves to reduce symptoms of PTS of the upper extremity is suggested [2,4,10,13].

Venous thromboembolism in other location

The predisposing factors of the patients with catheter-related thrombosis are similar to those with venous thromboembolism, including pulmonary embolism and upper or lower extremities deep vein thrombosis. Therefore, while evaluating patients suspected with catheter-related thrombosis by CTVPA techniques, the possibly superimposed venous thromboembolism should be carefully evaluated including bilateral pulmonary arteries (Fig. 5) and proximal femoral vein (Fig. 6) in the scan range. Combination of pulmonary infarction (Fig. 5) is sometimes detected with peripherally located wedge-shaped consolidation appearance [7].

Alternative diagnoses

Cancer-related superior vena cava syndrome

Cancer is the most common cause of superior vena cava (SVC) syndrome, either by direct invasion or external compression by the tumor mass. The CT appearance of SVC obstruction includes lack of opacification of the superior vena cava, an intraluminal filling defect or severe narrowing of the superior vena cava, and visualization of collateral vascular channels (Fig. 6). Radiotherapy is the first-line treatment for cancer-related SVC syndrome. Other oncologic treatment (surgery or chemotherapy) and endovascular treatment with angioplasty or stent placement can also be considered for these patients.

Compression of brachiocephalic vein by native anatomy or other disease

Left brachiocephalic vein is sometimes compressed between the aortic arch branches and the sternum (Fig .7) [6]. Other causes of extrinsic compression of left brachiocephalic vein include thyroid goiter (Fig. 8), mediastinal inflammatory pseudotumor (for example, fibrosing mediastinitis) and malignancy.

Infection

Clinically, catheter-related infection can be local (cellulitis) or systemic (catheter-related blood stream infection) [12]. The risk of infection is increased markedly after 4 days of catheterization, especially in patients with multi-lumen catheters or underlying malignancies [14]. Image findings on MDCT include induration or edematous appearance around the catheter (Fig. 9), thickening of a vessel wall, intraluminal air, and even thrombosis. If septicemia involves lung, it may lead to pneumonia or septic emboli, which would presented as cavitated consolidative lesions [7,14]. Treatment with antibiotics and removal of the indwelling catheter are recommended [1,10,12].

Lymphedema

The diagnosis of lymphedema can be made through history taking (prior surgical or radiation therapy for malignancy or trauma history) and physical examination (pitting edema in early stage and fibrosis in late stage) [15]. Indirect CTvenography can further confirm the diagnosis and exclude thrombus formation. CT appearance of lymphedema include skin thickening (Fig . 10), "honeycombing" of the subcutaneous tissue, epifascial #uid lakes, and the absence of edema within muscular compartments [15]. Conservative treatment such as compression garment use, intensive bandaging and lymphatic massage is the mainstay of therapy [15].

Images for this section:

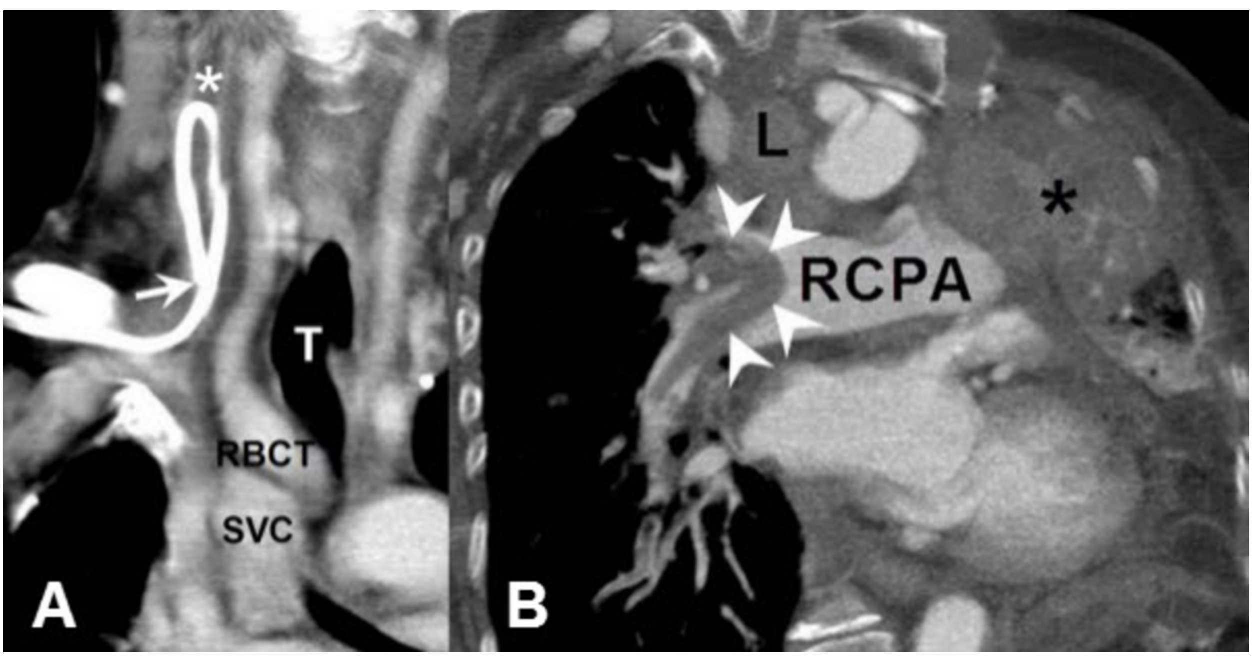

Fig. 1: A 65-year-old female with advanced lung cancer and mediastinal lymph-node metastases post insertion of central venous catheter via right subclavian vein presented with right neck pain and facial swelling. MDCT was arranged to exclude superior vena cava syndrome. The final diagnosis was kinking of the catheter tip with acute catheter-related thrombosis. Pulmonary embolism was also found. a. Coronal 2-mm maximum-intensity-projection image shows kinking of the catheter tip (arrow) in right internal jugular vein with thrombus formation (white asterisk), which causes venous stasis. The thrombus is diagnosed to be 'acute' (which means anticoagulation is likely to be effective) due to distended venous caliber, enhancing venous wall and mild perivenous edema. RBCT = right brachiocephalic trunk, SVC = superior vena cava, T = trachea. b. Coronal 2-mm maximum-intensity-projection image shows saddle-shaped, low-attenuation filling defect (arrowheads) with trailing edge in right central pulmonary artery (RCPA), right upper and lower pulmonary arteries, indicating acute pulmonary embolism. In addition, a lung mass over left upper lobe (asterisk) with mediastinal lymphadenopathy (L) is also noted, compatible with lung cancer with lymph node involvement. After 2 weeks of anticoagulation therapy, the symptoms were relieved.

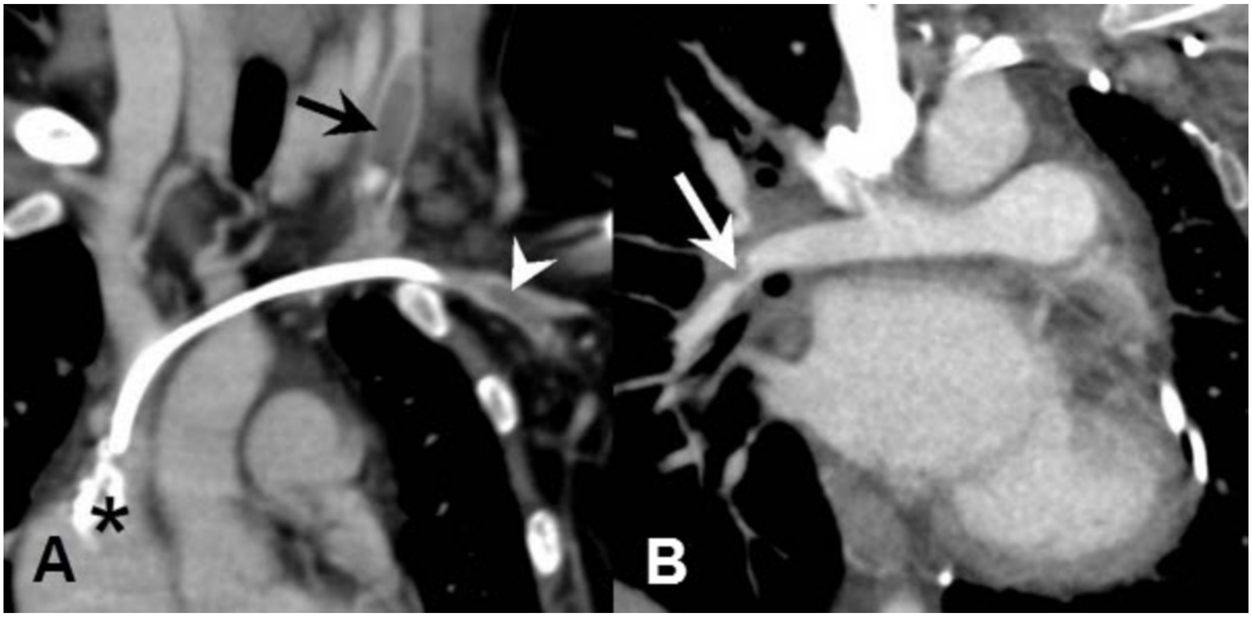

Fig. 2: A 11-year-old boy with acute lymphoblastic leukemia post insertion of chemoport via left subclavian vein for more than one year, now presented with superior vena cava syndrome. This case shows that MDCT is capable of demonstrating pulmonary embolism, acute and chronic thrombus formation simultaneously. a. Oblique coronal maximum-intensity-projection image shows indwelling chemoport via left subclavian vein. Acute catheter-related thromboses in left internal jugular vein (arrow) and left axillary vein (arrowhead) are detected with distended venous lumen and wall enhancement. In addition, a calcified thrombus in right atrium (asterisk) attached to the catheter tip is also noted. b. Oblique coronal 2-mm thin-section maximum-intensity-projection image shows one small thromboembolus (arrow), forming obtuse angle with the attaching vessel wall of right lower pulmonary artery, indicative of chronic pulmonary embolism.

Surgical resection of the right atrium chronic thrombi, removal of the chemoport and subsequent pharmaceutical treatment with heparin and warfarin were done and the patient's symptoms relived shortly thereafter.

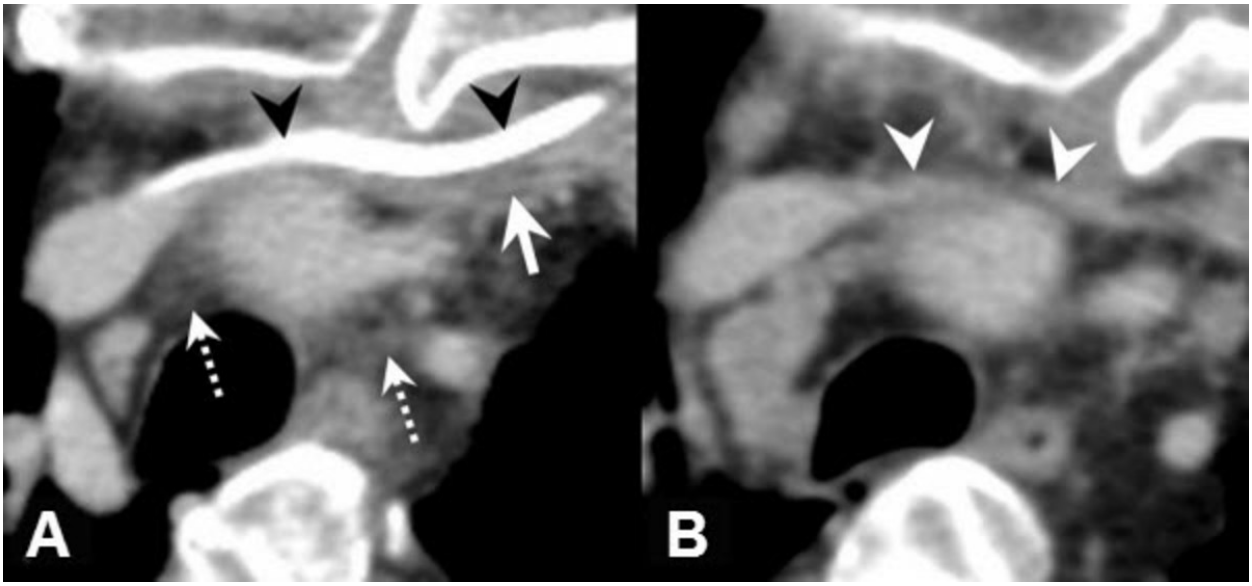

Fig. 3: A 59-year-old male, with history of non-small cell lung cancer with lung to lung and mediastinal metastases. Acute catheter-related thrombosis was diagnosed and treated with catheter removal and anticoagulation. Fifteen months later, chronic thromboembolism with lumen obliteration was found by MDCT. This case demonstrates the powerful capability of MDCT in diagnosis and follow-up. a. Oblique axial maximum-intensity-projection image shows acute catheter-related thrombosis (arrow) adjacent to the indwelling catheter (black arrowheads) in left brachiocephalic vein, which has the characteristics of distended venous lumen, enhancing venous wall and perivenous edema (dashed arrows). The catheter was removed three days later with anticoagulant treatment. The symptoms were relieved 7 days later. b. MDCT was done again 15 months later due to progressive painful swelling of left upper limb and chest wall. Oblique axial maximum-intensity-projection image taken at the same level as figure a, shows obliterated lumen of left brachiocephalic vein with fibrosis (white arrowheads). A lot of chest wall collateral veins were formed for venous return (not shown).

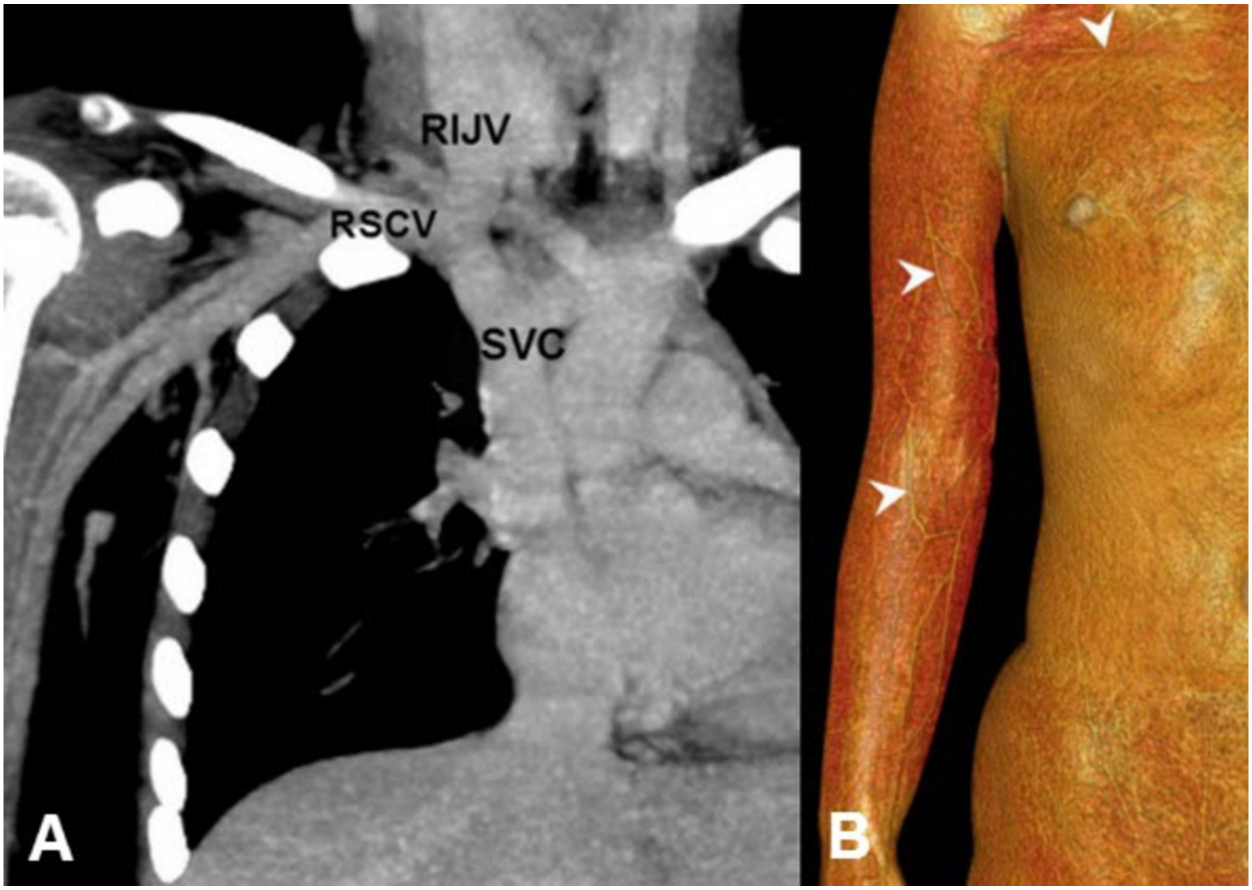

Fig. 4: A 10-year-old girl, with previous history of catheter-related thrombosis in right upper limb post removal of catheter and anticoagulation treatment one year ago, presented with persistent mild swelling of right upper limb. MDCT confirmed venous patency and no residual thrombus but engorged superficial veins in right upper limb, postthrombotic syndrome was diagnosed. a. Oblique coronal 10-mm thick-section maximum-intensity-projection image shows patent veins over right upper limb without thrombus formation (also confirmed on axial images, not shown). RIJV = right internal jugular vein, RSCV = right subclavian vein, SVC = superior vena cava. b. Volume-rendered image from anterior view shows engorged superficial veins (arrowheads) as collaterals and mild swelling of right upper limb and right upper chest wall. According to the image finding and her past history of indwelling catheter with catheter-related thrombosis in right upper limb, postthrombotic syndrome was diagnosed. Observation and physical rehabilitation were recommended.

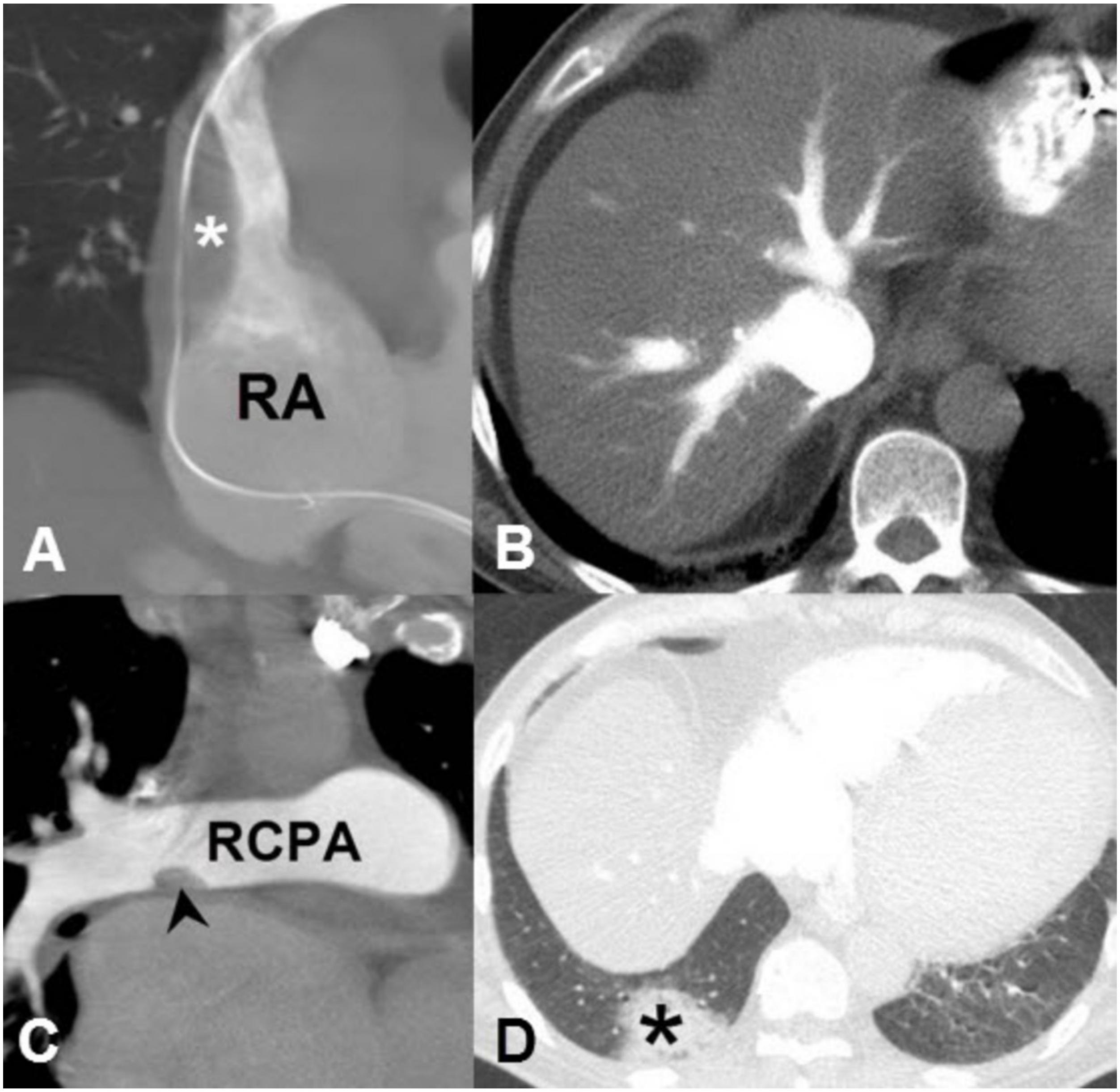

Fig. 5: A 57-year-old male received cardiac resynchronization therapy two months ago, now presented with aggravated shortness of breath. MDCT demonstrated catheter-related thrombosis with superimposed pulmonary embolism and pulmonary infarction. a. Oblique sagittal 10-mm thick-section image shows a low attenuation filling defect (white asterisk) located over the junction of superior vena cava and right atrium (RA), which is attached on the pacing wire, catheter-related thrombosis is diagnosed. b. Axial image shows contrast medium in dilated IVC and hepatic veins, so-called dense abdominal vein sign, which is indicative of right heart failure. c. Oblique coronal 3-mm image shows a small pulmonary emboli (arrowhead) attached on the wall of right central pulmonary artery. RCPA= right central pulmonary artery. d. Axial image in lung window shows wedge-shaped pulmonary infarction over right basal lung (black asterisk). Due to combination of catheter-related thrombosis and pulmonary embolism, anticoagulants were given. There were no emboli in the follow-up CT three months later (not shown).

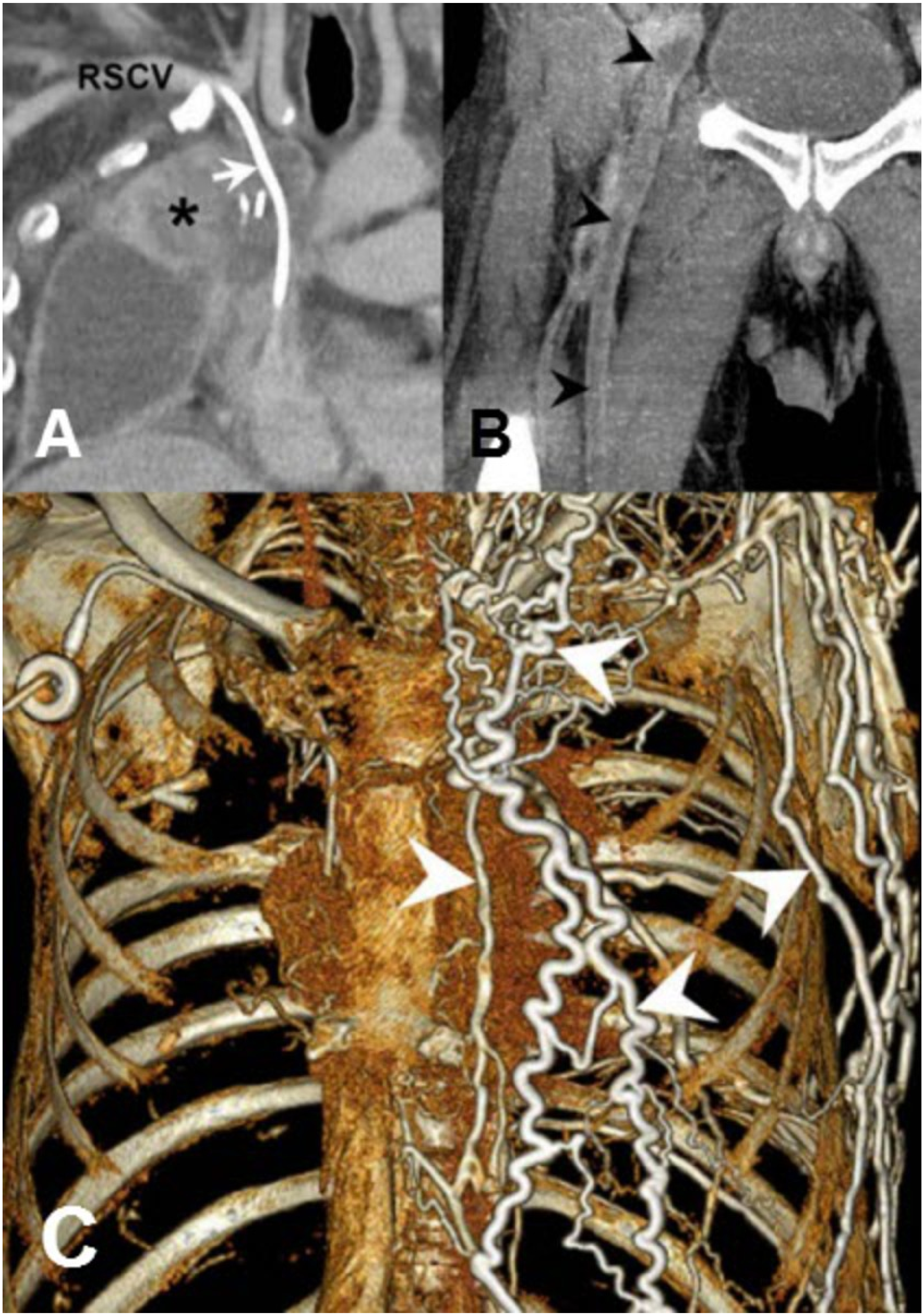
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Fig. 6: Fig. 6 - A 48-year-old male with right-upper-lobe lung cancer with brain and bone metastases, presented with right upper and lower limbs swelling. Cancer related superior vena cava (SVC) syndrome and superimposing venous thromboembolism, including pulmonary embolism (not shown in the illustrated images) and lower limbs deep vein thrombosis, were diagnosed by MDCT. This case demonstrates that MDCT can not only provide a correct diagnosis of the underlying problem but also can find superimposing deep vein thrombosis in proximal femoral veins within the scan range. a. Coronal 10-mm thick-section maximum-intensity-projection image shows right-upper-lobe lung cancer (asterisk) with total compression and obstruction of SVC (white arrowhead), which indicated cancer-related SVC syndrome. Malignant pleural effusion with pleural thickening is also disclosed. b. Coronal 2-mm thin-section maximum-intensity-projection image shows filling defects with low attenuation in right common iliac vein and right femoral vein (arrowheads) till the end of the scan range, superimposed deep vein thrombosis is diagnosed. c. Anterior view of volume rendered image shows multiple engorged collaterals (arrowheads) bypassing the obstructed SVC. The patient received radiotherapy for cancer related SVC syndrome and anticoagulants for venous thomboembolism after MDCT. The symptoms were relieved one week later.

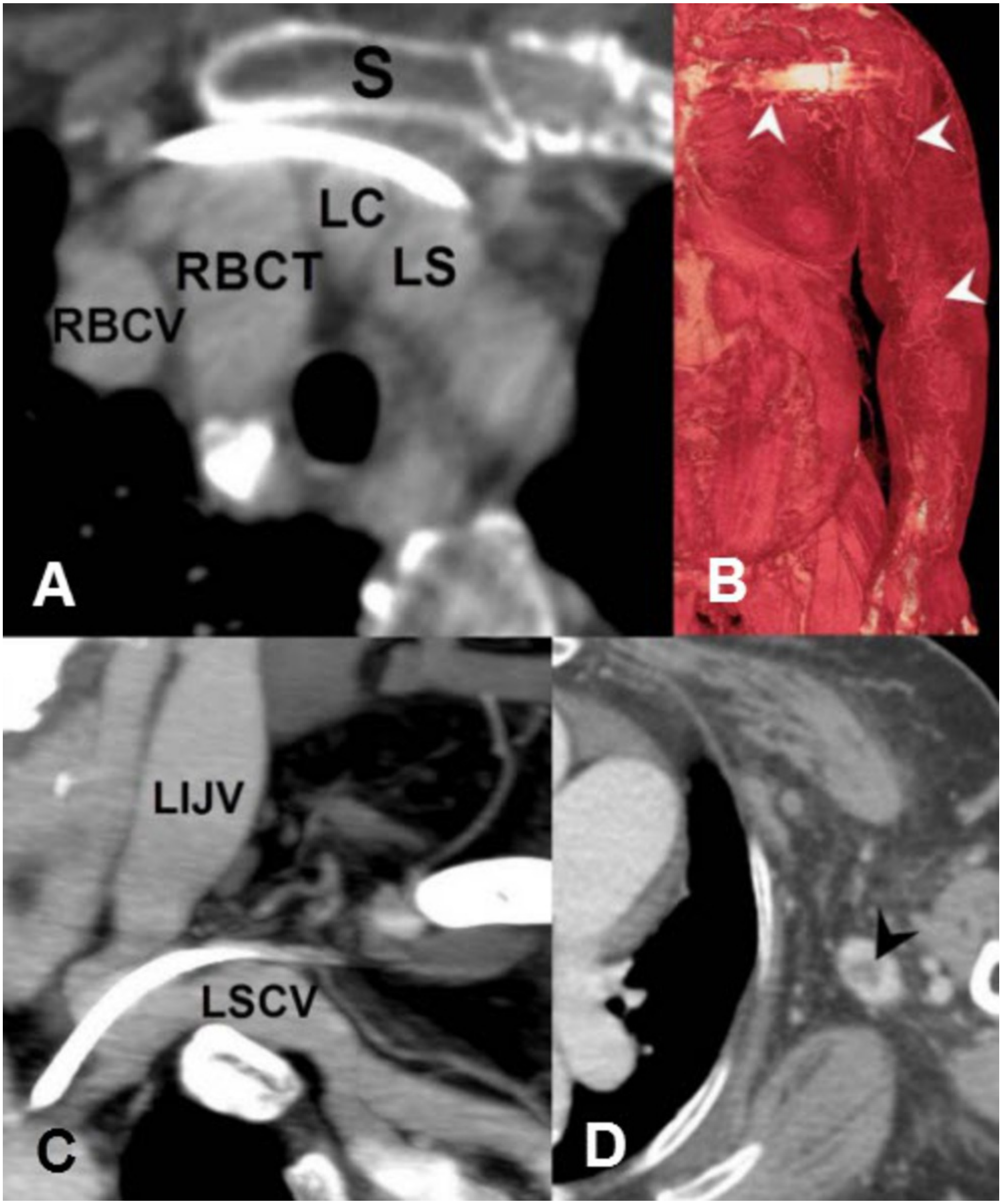

Fig. 7: A 73-year-old female with sick sinus syndrome post permanent pacemaker implantation via left subclavian vein, presented with left upper limb swelling for 6 months. MDCT demonstrated compression of left brachiocephalic vein among right brachiocephalic trunk, left common carotid artery and sternum, which subsequently was complicated with left upper limb venous stasis and thrombus formation. a. Oblique 10-mm thick-section axial maximum-intensity-projection image shows pacemaker in left

brachiocephalic vein which is severely compressed between right brachiocephalic trunk (RBCT), left common carotid artery (LC) and sternum (S). Venous stasis of left upper limb and multiple collaterals over left chest wall are demonstrated in Fig. 7b. RBCV = right brachiocephalic vein, LS = left subclavian artery. b. Anterior view of volume rendered image shows multiple collaterals (arrowheads) over left upper chest wall and left upper limb with soft tissue swelling, caused by venous stasis. c. Oblique coronal 10-mm thick-section maximum-intensity-projection image shows no catheter-related thrombosis in left internal jugular vein (LIJV) or left subclavian vein (LSCV). d. Axial image shows a small thrombus (arrowhead) in left axillary vein. The patient was treated with heparin and warfarin, and then symptoms relieved. However, recurrent thrombosis was noted 4 months later (not shown) due to venous stasis caused by the same anatomic problem (compression of left brachiocephalic vein).

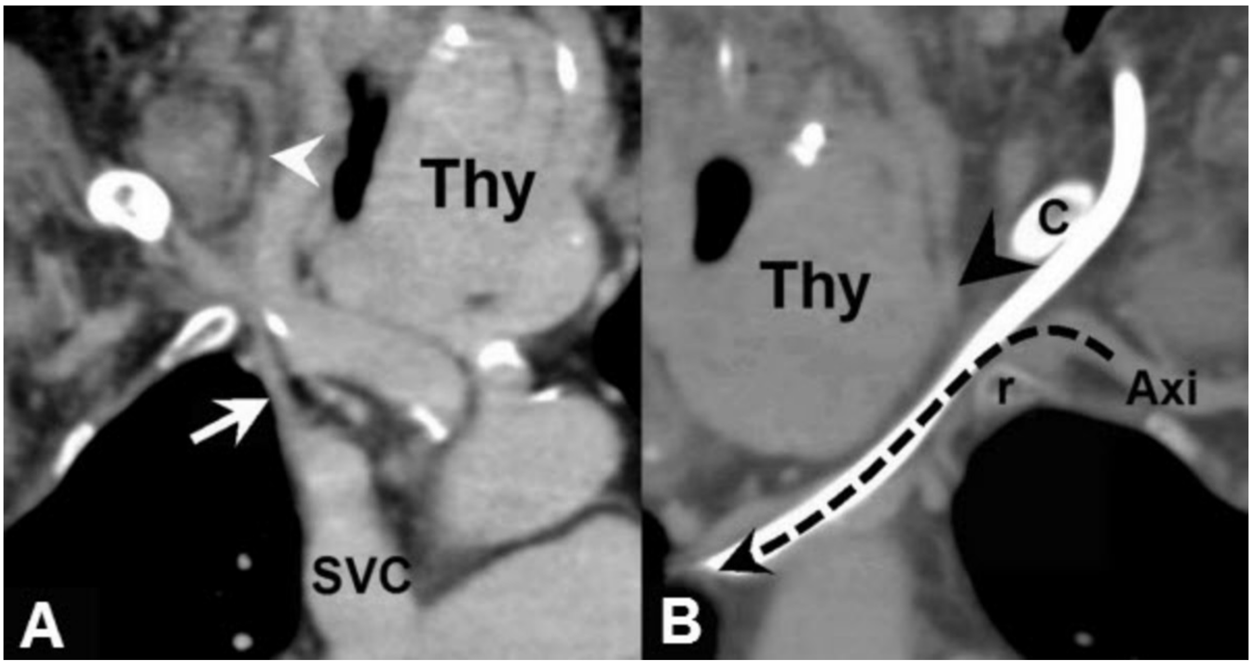

Fig. 8: Fig. 8 - A 78-year-old female under hemodialysis, using Hickman catheter from left subclavian vein for one week, presented with left neck, upper arm and anterior chest wall swelling. MDCT demonstrated right brachiocephalic vein occlusion and left brachiocephalic vein compression by thyroid goiter. a. Oblique coronal 10-mm thick-section maximum-intensity-projection image shows fibrosis and obliteration of right internal jugular vein (arrowhead) and right brachiocephalic vein (arrow), as a long-term complication of previous catheterization. Engorged left lobe of thyroid gland (Thy) is also seen in this image. SVC = superior vena cava. b. Oblique coronal 10-mm thick-section maximum-intensity-projection image shows left internal jugular vein (arrowhead) and left brachiocephalic vein, which are severely compressed and displaced by enlarged left thyroid gland (Thy). Indwelling Hickman catheter further cause venous stasis of left brachiocephalic vein, left internal jugular vein and left axillary vein (Axi) (dash black arrow). The above-mentioned conditions contributed to the symptoms of the patient. The

catheter was removed one month later due to lumen obstruction, and peritoneal dialysis was then performed due to difficult catheterization. r=left first rib, c=left clavicle.

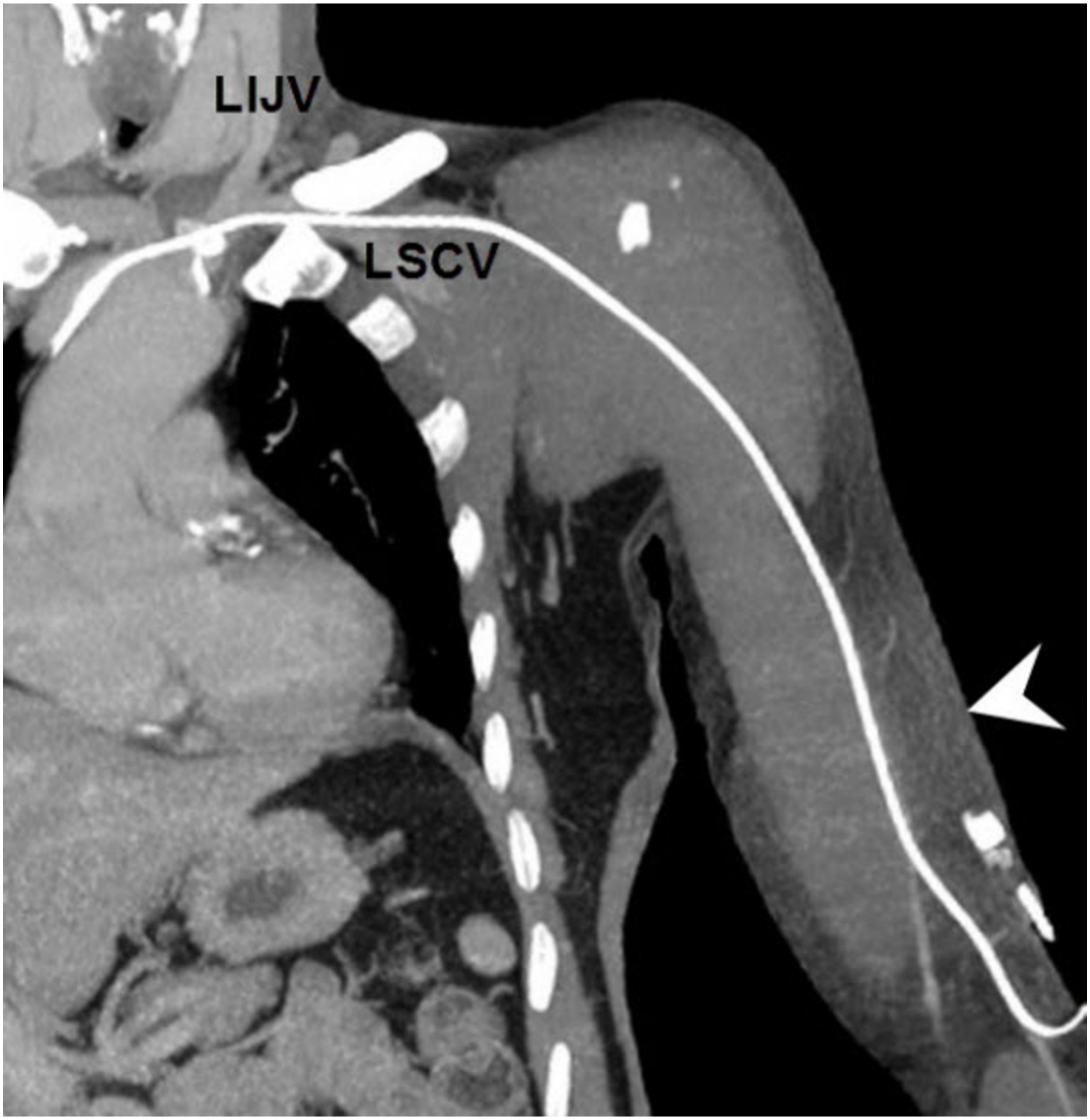

Fig. 9: A 68-year-old male with right-upper-lobe lung cancer with mediastinal lymphadenopathy post PICC insertion for one week, presented with left upper limb painful swelling and tenderness, which began two days ago. MDCT was done and oblique coronal 10-mm thick-section maximum-intensity-projection image shows focal edematous appearance around the catheter over distal portion of left arm (white arrowhead). No deep vein thrombosis is noted. Under the impression of cellulitis, PICC was then removed and subsequent tip culture showed coagulase-negative staphylococci.

Intravenous oxacillin was used and symptoms were relieved one week later. LIJV = left internal jugular vein, LSCV = left subclavian vein.

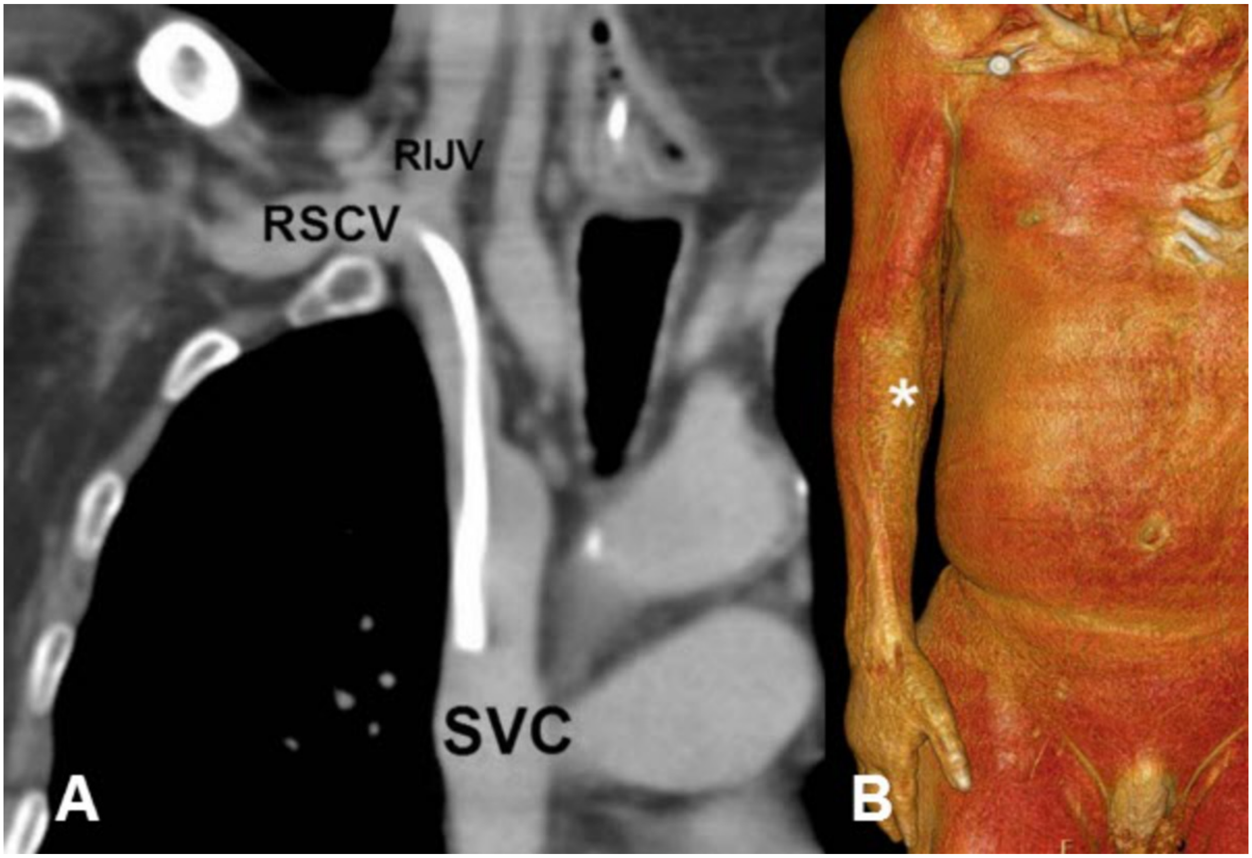

Fig. 10: A 74-year-old male with hypopharyngeal cancer post total laryngectomy, radiotherapy and chemotherapy, presented with right upper limb edema for about three weeks. No infection signs were noted. Lymphedema was diagnosed by exclusion. a. Oblique coronal 10-mm thick-section maximum-intensity-projection image shows no deep vein thrombosis. RSCV = right subclavian vein, RIJV = right internal jugular vein, SVC = superior vena cava. b. Anterior view of volume rendered image shows right upper limb swelling (asterisk). Under the diagnosis of lymphedema, rehabilitation was done and the edema resolved 5 days later.

Conclusion

With proper scanning techniques and interpretation, MDCT can be a powerful image modality to comprehensively evaluate patients suspected with catheter-related thrombosis and their treatment effect. Radiologists familiar with these various conditions of catheter-related thrombosis can lead to early and proper management to alleviate the patients' symptoms and to prevent subsequent complications.

Personal Information

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