Learning objectives

To emphasize the importance and utility of computed tomography angiography (CTA) application in neurosurgery, vascular surgery, neurology and internal medicine, and to instruct young radiologists about the essence of CTA through presentation of usual and unusual series of cases.
Background

A conventional angiogram was considered as a gold standard for diagnosis of arterial diseases. A development in computer technology provides a significant implementation of different diagnostic tool and software packages which are used for better visualization and evaluation of arteries. CTA becomes a powerful diagnostic modality for a detection of different vascular abnormalities. As minimally invasive technique, which gives it an advantage over conventional angiography, CTA gradually takes significant place in daily radiological practice. There are numerous indications for practical application of CTA.

Clinical conditions such as intracranial hemorrhage caused by rupture of aneurysm or arteriovenous malformation, ischemic brain strokes, pulmonary thromboembolia and dissection of thoracic or abdominal aorta, coronary stenosis, visceral stenosis/occlusion and peripheral vascular diseases can be diagnosed using CTA. Also, computed tomography has a role in focal trauma, but it is limited due to artifacts from metal implants, dental implants or shrapnel. The patient’s radiation exposure to CTA modality is the one negative fact. Effective radiation dose delivered during the CTA exam depends on particular part of the body. A mean estimated effective dose for CT brain angiography is 3.2-7.6 mSv, but effective dose for cardiac CTA is 4.4-5.8 mSv. The average patient dose for peripheral CTA examination is 7.47 mSv. CTA examination in our department (Clinical Centre of Vojodina- Radiology Centre, Novi Sad) was performed with 16-slice and 64-slice CT scanners, mostly in patients with carotid, visceral and peripheral steno-occlusive diseases, also with intracranial and abdominal aneurysm. CT angiography includes topogram, precontrast and contrast medium injection scan. A topogram is useful in evaluation of position of calcified artery or stent position. A precontrast scanning is useful in evaluation of mural haematoma or hemorrhage, calcifications or for determination of place to set the cursor for bolus tracking. Patients get intravenous nonionic water-soluble iodine contrast in dose of 1.2 ml per 1 kg body weight (usually Iodixanol 320 mg/mL or Iohexol 350 mg/mL) and saline for contrast medium injection scan. Monophase or biphasic contrast injection was used during the CT angiography. The biphasic injection of contrast media is mostly used for CTA of lower extremities. Before an examination all information about CTA procedure was given to patients and they sign written permission for CTA exam. A serum creatinine is obtained before the injection of contrast medium in all patients who at risk for contrast induced nephrotoxicity (CIN). Indication for a serum creatinine measurements before intravascular administration of iodinated contrast medium are age above 60 years, history of diabetes mellitus, and history of medicament treated arterial hypertension, and renal diseases (cancer, dialysis, single kidney, kidney transplant or renal surgery). In special cases when CTA examination must be done in patients who underwent hemodyalisis, patients require premedication and hydration. There were not data about adverse acute or delayed reactions to contrast media in our patients after the CTA procedure. Technical parameters for CT angiography of all parts of the body including brain, neck, thorax, cardiac, abdominal aorta, upper and lower extremities on 16-slice and 64-slice were used according to Siemens protocols.
A successful CT angiography depends on several technical items including scanning parameters, precise application of intravenous contrast material and its delivery through the vessel, and correct timing of data acquisition. There are 1000-5000 images as a result of CTA reconstruction of data sets after one examination. Post processing procedures that include three-dimensional reconstructions (3D-CTA) such as MPR, MIP and VRT are very important parts of CTA modality. These volume rendering techniques have applications in many medical fields such as oncology, internal medicine, forensic medicine, and orthopedics and for planning surgery.
Imaging findings OR Procedure details

The utility of CTA examination in many situations are presented and illustrated with detailed descriptions of usual and unusual individual conditions.

CEREBRAL ARTERIES

CT angiography is widely used for evaluation of cerebral arteries especially in neurosurgical and neurological conditions such as subarachnoidal hemorrhage (SAH) and hemorrhagic or ischemic stroke. The CTA modality provides information about diameter, location, number of aneurysms and also about presence of intraluminal thrombus. Sensitivity of CT angiography for detection of intracranial malformation is between 81-90% and specificity is 93%. CTA is also powerful to detect stenosis and occlusion of arteries. The common cause of intracranial hemorrhage is the rupture of intracranial aneurysms or arteriovenous malformation. The intracranial aneurysm is detected in 3-6% of general population, with female predominance, but some of them were detected only at autopsy. A small aneurysm is defined as aneurysm with diameter below 10 mm, large aneurysms have diameter between 10-25 mm, but giant aneurysms have diameter above 25 mm. The most frequently aneurysms are located at the bifurcation of arteries, usually in the anterior circulation in about 80-85%, while the 15-20% aneurysms are located in the posterior circulation, mostly arise from the basilar artery bifurcation. There are numerous risk factors for aneurysm formation such as genetic factors (dominant polycystic kidney disease, Marfan’s syndrome, Neurofibromatosis I) or environmental factors (cigarette smoking, alcohol consumption, arterial hypertension, oral contraceptives). The treatment of aneurysms is the domain of neurosurgery (surgical clipping) but endovascular treatment (coil embolisation) of aneurysms is designed for interventional radiologists.

Vertebrobasilar artery aneurysms occur in 15% of all intracranial aneurysms. The symptoms of vertebrobasilar dolichoectasia and aneurysm in patients include subarachnoidal hemorrhage, ischemic stroke, cranial nerves compression or hydrocephalus. The aneurysms of basilar artery are not common (occur in less than 1%) and their surgical treatment are very difficult with unpredictable outcome.

The brain arteriovenous malformations (AVMs) are a group of brain vascular lesions. AVMs are congenital abnormal vascular connections between the arterial feeder which supply the brain tissue and veins that drain the brain. AVM occur with two forms: nidal and fistulous. This lesion is usually connected with high possibility for occurrence of
intracranial hemorrhage or decrease of cerebral perfusion leading to neurological deficit. There are several treatment modalities for AVM: endovascular treatment, surgery or radiotherapy intervention.

**The brain ischemic stroke** is the urgent condition in medicine. It is major cause of disability in adult people. The early signs of ischemic brain stroke are confirmed by non contrast CT scan and additional modalities are CT angiography and CT perfusion that have a significant role in decision about thrombolysis. CTA could show the occlusion site and collateral flow and help in the characterization of plaque on carotid arteries or endocranial vessels. A modern treatment approach to patients with cerebrovascular ischemic infarction is the brain tissue reperfusion with implementation of fibrinolytic therapy.

Images for this section: Fig.1- 11

**THORACIC AORTA, PULMONARY AND CORONARY ARTERIES**

CT angiography has irreplaceable role in diagnostic of pulmonary embolism. It is the most practical routine imaging diagnostic test for pulmonary thrombosis in daily medicine associated with D-dimer analysis. The effective dose of CTA for patients with suspected pulmonary embolism is about 5-7mSv, but dose reduction was achieved by decreasing of kV which is recommended for children and low to normal weight patients. A poor quality of CTA method could be if there are several factors such as patient's overweight or motion and weak contrast filling of pulmonary arteries. Furthermore, CTA is a fast, inexpensive and available diagnostic method and has a key role in diagnosis of many emergency conditions such as thoracoabdominal aneurysms and dissection and also in diagnosis of heart anomaly and coronary artery stenosis.

**Pulmonary embolism (PE)** is common disease in developed countries and the third cause of death after myocardial infarction and brain stroke. In 70-80% embolus originates from deep veins of legs and about 10-15% from pelvic vessels. During the CTA exam the main, lobar, segmental and sub segmental arteries are evaluated in patient suspected on pulmonary thrombus for both lungs. There are two forms of PE: acute and chronic. The filling contrast defect in the lumen of artery is the CTA sign of PE. The specific sign in arteries ("polo mint" or "railway track") could be detected in acute forms of PE. The pulmonary artery with diameter over 33 mm and pericardial effusion are the signs of chronic PE. Other, but nonspecific signs of PE could be pleural effusion, mosaic attenuation of lung parenchyma or lung infarction. The special attention should be given to the right ventricle.
**Aortic aneurysm** is defined as dilatation whose diameter is at least 1.5 times larger than normal diameter. A various pathogen factors are associated with descending thoracic and thoracoabdominal aortic aneurysms such as atherosclerosis, degeneration of vascular smooth muscle cells, chronic inflammation, connective tissue disorders and infections. The important mechanism of aortic aneurysm formation is the group of factors that include genetics and mechanical stress such as destruction and remodeling of aortic wall, turbulent blood flow, inflammation and angiogenesis. Patients with aortic aneurysm usually have co morbidities-pulmonary or heart diseases which could take into the consideration in evaluation of operative risk and patient's clinical outcome. A both type of aneurysm, descenderit thoracic aortic aneurysm and thoracoabdominal aortic aneurysm are classified into IV category and repaired by surgery. Endovascular aneurysm repair (EVAR) is relatively new technique which uses stent-graft for repairing abdominal or thoracic (TEVAR) aneurysm before its rupture. One of the complications after this method is the appearance of the endoleaks which are categorized in five types.

**Coronary artery disease (CAD)** is widespread all over the world with the high morbidity and serious complications-cerebrovascular accidents, myocardial infarction or death. A good management of CAD and early diagnosis for patients and clinicians provide reduction of morbidity and mortality. The special focus is on patients with coronary anomaly, although the prevalence of that condition in general population is less than 1%. Today the CTA application offers some benefits in early diagnosis of diseases in children. A cardiac catheterization is common method for diagnosis of coronary artery lesions, but invasive, with a complication rate about 1-2%. Technological improvement has contributed to better testing, less invasive and rapid diagnostic method like coronary CT angiography. Agatston score is widely in use for detection of calcium deposits in coronary arteries which could be measured on non contrast cardiac CT scan before the administration of intravenous contrast. A measurement is based on the CT number (Hounsfield units) and the area of calcium deposits. ECG gated, or retrospective scanning is technique we use in our department for coronary CTA on Siemens Cardiac Sensation 64-slice scanner. Several indications for this technique are: patients with small or mild risk for coronary stenosis, evaluation of anomaly of coronary artery or heart tumor lesions, dilemmas after catheterization, stent or bypass evaluation, preoperative evaluation of coronary arteries.

Images for this section: Fig.12-20

**ABDOMINAL AORTA AND VISCERAL ARTERIES**

**Mycotic abdominal aneurysm** of the aorta is rare condition but lead to fatal outcome because of the rupture and consequently sepsis in patients. Used together, clinical analysis and imaging diagnostic give a final diagnosis. In study of Finseth and Abbott the pathogenesis and mechanism of infective focus formation
for mycotic aneurysm could be primary, secondary and cryptogenic. On CT scan one sign of mycotic aneurysm is low attenuation of perianeurysmal collection with rim contrast enhancement.

In literature, there is data about small percent of aneurysms of visceral arteries in about 0.2% of general population. According to its frequency, aneurysms of lienal artery are on the third place, after abdominal aortic aneurysm and iliac arteries. Some of them are recognized only post mortem. If it is a symptomatic, patients usually complain of long term pain in abdomen. A rupture of visceral aneurysm occurs in about 25% and surgical treatment is essential. Also, the mesenteric ischemia is urgent condition which is very important for clinicians and radiologist. Because of possibility of fatal outcome for patients it needs a rapid diagnosis and therapy. Its presentation could be acute or chronic and there are numerous factors that contribute to mesenteric ischemia development such as mixed, lipid or calcified plaque formation, embolus from abdominal or visceral aneurysm or from heart, atherosclerosis, vasculitis or fibromuscular dysplasia.

Images for this section: Fig.21-27

PERIPHERAL CIRCULATION (upper and lower extremities)

Arterial steno-occlusive diseases of upper and lower extremities could be local or systemic. Multiple pathogen factors are responsible for its genesis such as atherosclerosis, fibromuscular dysplasia, radiation therapy, hypercoaguability, connective-tissue diseases, arteritis, cigarette smoking or trauma. The most frequent symptom of upper limb arterial occlusion is digital gangrene and the most affected is the brachial artery.

In lower extremities, steno occlusive diseases are common on the femoral, popliteal and infrapopliteal arteries. Not so rare, the popliteal artery occlusion is associated with femur or knee dislocations. Treatments for steno-occlusive disease in lower limbs include thrombolytic infusion, percutaneous transluminal angioplasty (PTA), the stent positioning or bypass graft. The stenosis severity determines whether to apply PTA or surgery. CTA examination with the usage of 3D reconstructions in post processing gives excellent information about arterial patency, localization of calcified or mixed plaque and stenosis or occlusion that have big influence on vascular planning and surgery. Bypass graft and a stent position are monitored after vascular intervention by CTA. Moreover, incidental findings and nonvascular lesions could be found during the CTA.

A normal diameter of popliteal artery is 0.7-1 cm. The sign of growing popliteal artery aneurysm is usually pulsatile mass in the popliteal fossa. This aneurysm is common and very often associated with femoral artery aneurysm. Popliteal aneurysm could be true and false and symptoms could be acute and chronic. Thromboembolism or aneurysm
rupture is acute condition, but ischemia of lower limbs with claudicating is connected with chronic state in patients. In about 45% of patients, aneurysms of popliteal artery are asymptomatic.

Images for this section: Fig 28-31
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**Fig. 1:** Aneurysm of basilar artery

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Fig. 2: Fusiform aneurysm of the left vertebral and basilar artery

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Fig. 3: Aneurysm of pericalosal artery

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Fig. 4: Fusiform aneurysm of the left internal carotid artery

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Fig. 5: Small aneurysm of the left cerebral media artery (M2)

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Fig. 6: Arteriovenous malformation_ blood supply ACM sin., ACA dex et AComP, vein drainage- superior sagital sinus et sinus transfersus sin.

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Fig. 7: AV malformation in the left temporal lobe

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Fig. 8: AV malformation in the right temporal lobe

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**Fig. 9:** Hemorrhage caused by AV malformation

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Fig. 10: Significant stenosis (calcified plaque) of the common carotid and internal carotid artery

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Fig. 11: Occlusion of the right cerebral media artery

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Fig. 12: Pulmonary thromboembolia in segmental branches of the right pulmonary artery

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Fig. 13: Thromboembolus in both pulmonary arteries

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**Fig. 14:** Pulmonary tromboembolia in the branches of the right pulmonary artery

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Fig. 15: Calcifications in the left coronary artery

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Fig. 16: Normal lumen of the right coronary artery

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Fig. 17: Rupture of the thoracoabdominal aneurysm

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**Fig. 18:** Aneurysm with dissection of the thoracic aorta

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Fig. 19: Dissection of the thoracic aorta with aneurysm of abdominal aorta (VRT)

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Fig. 20: Thoracic aneurysm with abdominal aneurysm dissection

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Fig. 21: Mycotic abdominal aneurysm

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Fig. 22: Rupture of abdominal aneurysm with hematoma on the left side

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Fig. 23: Thrombosis of abdominal aorta aneurysm

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Fig. 24: Lienal artery aneurysm

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Fig. 25: Occlusion of superior mesenteric artery

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Fig. 26: Liver and spleen necrosis as consequences of air in portal system and visceral artery occlusion

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Fig. 27: After EVAR procedure without endoleak

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**Fig. 28:** Brachial artery occlusion

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**Fig. 29:** Occlusion of P1 segment of popliteal artery

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Fig. 30: Bilateral popliteal artery aneurysm

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**Fig. 31:** Aneurysm of the right common iliac artery

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Conclusion

Many qualities of CTA provide its great potential to replace conventional angiography. CTA is very useful in prompt diagnosis of different types of vascular pathology or injury-from head to feet. Moreover, it can be powerful method in treatment planning for patients.
References


CEREBRAL ANGIOGRAPHY


THORACIC AORTA, PULMONARY AND CORONARY ARTERIES


Halliburton SS, Stillman AE, White RD. Noninvasive quantification of coronary artery calcification: Methods and prognostic value. Cleveland clinic journal of medicine 69(3); 2002: 6-11.


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Fiolic Z, Gregorek A, Snajdar I, Hudorovic N. Concomitant symptomatic aneurysms of celiac trunk and superior mesenteric artery. Macedonian Journal of Medical Sciences 3(1); 2010: 54-56.


PERIPHERAL CIRCULATION (upper and lower extremities)