Spectrum of incidental acute and emergency findings on metabolic PET/CT in oncology patients

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Authors: M. Novikov; Kyiv/UA
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Learning objectives

1. Demonstrate the spectrum of acute and emergency findings, incidentally encountered during metabolic PET/CT exams in oncology patients.
2. Illustrate CT and PET appearance of these important findings, highlighting the additive value of structural and metabolic imaging data.
Metabolic PET/CT is widely used in oncology for a range of purposes, including diagnosis, staging, and restaging of malignancies, and becomes a routine imaging exam for certain clinical situations. Standard PET/CT protocols include imaging of the whole body, at least torso, and frequently - total body with head and limbs, subsequently, not only oncological findings but also a wide range of incidental conditions and lesions are frequently imaged. Some of them may be of urgent importance, and their timely detection often changes short-time patient management. In certain oncology patients, these findings may remain clinically silent or do not demonstrate typical clinical signs and symptoms at the time of referral, especially in patients with extensive disease, or receiving high doses of pain medications.

Metabolic PET/CT is not routinely aimed at diagnosis of urgent and acute findings, nevertheless, development of malignant tumors, especially in setting of locally advanced and metastatic disease, may produce a series of emergent and potentially life-threatening conditions, caused by primary tumor and/or its metastasis including bleedings, thrombosis, various combinations of compression and/or obstruction of blood vessels and hollow structures (airways, bowel loops etc), significant mass-effects in neural tissues.

Imaging technique behind metabolic PET/CT requires time and certain patient preparation, thus, it is highly unlikely for a critical condition patient to be undergoing this procedure, consequently, imaging of critical conditions with this modality is relatively low. Nevertheless, various acute and urgent findings, especially representing conditions that may potentially develop into life-threatening conditions in oncologic patients are not so rare in PET/CT imaging. These findings are of significant importance, especially in outpatients, as they are likely to change short-time management in those patients who are not routinely examined and observed on a daily basis. Also, it is important to mention, that certain portion of these finding may not be caused or connected directly to malignant disease, and represent a «stand-alone» pathologic conditions.
Findings and procedure details

Central nervous system conditions

- **Cerebral herniation**
  - Shift of cerebral tissue from its normal location, into an adjacent space due to mass effect.
  - Most common causes of cerebral herniation in cancer patients - primary and metastatic tumors, massive intracranial hemorrhage.
  - FDG PET/CT is rarely used for imaging of primary brain tumors, most likely cerebral herniation will be encountered as a result of metastatic disease. Primary tumors accounting for the majority of brain metastases are lung cancer, renal cell carcinoma, breast cancer and melanoma.
  - Depending on the location of a lesion, and subsequently the direction of mass-effect and displacement of certain structures there are several specific types of cerebral herniations with potential severe, life-threatening complications:
    - subfalcine (anterior cerebral artery territory infarction due to compression of its branches, contralateral hydrocephalus due to foramen of Monro obstruction);
    - transtentorial (extensive brainstem ischemia, ischemia of visual cortex due to posterior cerebral artery compression, brainstem hemorrhages (Duret hemorrhage), and contralateral cerebral crus indentation by the tentorium in severe cases);
    - tonsilar (brainstem compression against the clivus resulting in respiratory and cardiac centers damage).
  - Sensitivity of PET component alone is of limited value, especially for small lesions and may show both hyper- and hypometabolic foci corresponding to metastases, compared to high physiologic cortex uptake. Lesion’s mass effect and herniation are better assessed on CT component (Fig. 1 on page 10). Contrast-enhanced MRI remains a god standard for detection of metastatic brain lesions and their complications.

- **Spinal cord compression**
  - An emergency situation requiring prompt decompression to prevent permanent neurological impairment. There are numerous causes of cord compression, divided according to location and genesis of compressing mass.
  - In cancer patients primarily caused by vertebral metastasis, and epidural space metastasis (by means of hematogenous route, mainly carcinomas of the breast, lung, and prostate) and contiguous spread from tumors involving the paraspinal region (such as lymphoma, sarcoma, lung carcinoma).
The thoracic spine is the most frequent site of malignant compression, followed by the lumbosacral and the cervical spine. 

MR imaging without and with the use of gadolinium-based contrast material is the standard of reference for the diagnosis of malignant spinal cord compression and the whole-spine protocol is advised for multifocal involvement identification. PET/CT delivers both metabolic and anatomical data which assists in the differentiation of malignant and non-malignant cord compression (Fig. 2 on page 10, Fig. 3 on page 11).

Vascular conditions

- **Deep vein thrombosis, tumor thrombosis, and pulmonary embolism**
  - Development of deep venous thrombosis, tumor thrombosis, and subsequent embolism are important causes of pulmonary emboli in cancer patients (Fig. 4 on page 11, Fig. 5 on page 12, Fig. 6 on page 12).
  - The prevalence of coincidental pulmonary embolism is significantly higher in patients progressive cancer or those receiving chemotherapy. Cancer patients are also predisposed to develop deep vein thrombosis because of the direct thrombogenic effects of malignant tumors (Fig. 7 on page 13).
  - Thrombi harboring malignant cells are much more rarely encountered than the classic bland thrombi, but nonetheless are a serious finding with severe implications for staging, treatment, and prognosis (Fig. 8 on page 14).
  - Detection of such conditions on metabolic PET/CT exams is obviously highly dependent on CT portion technique, especially, regarding non-malignant and not metabolically avid thrombotic conditions. The inclusion of contrast-enhanced diagnostic/full-dose CT portion exam is able to demonstrate intravascular pathologies in full extent.
  - Combination of metabolic and structural data is useful in differentiating malignant and non-malignant origins of thrombi and distinguish different portions of large thrombotic masses.

- **Superior vena cava obstruction**
  - Can occur from extrinsic compression, intrinsic stenosis or thrombosis. Malignancies are responsible for superior vena cava (SVC) obstruction in about 78-97% of all cases. SVC syndrome is considered an oncologic emergency.
  - Lung carcinoma and lymphoma are the most common neoplasms associated with this condition (Fig. 9 on page 14).
  - Direct invasion or compression by the malignancy, with associated intraluminal thrombus formation, is the pathophysiologic basis of narrowing or complete SVC obstruction that subsequently impairs venous drainage from the head, neck, and upper extremities.
Clinical presentation depends on the speed, severity, and location of the obstruction, and the presence of superimposed thrombus and adequacy of collateral circulation. Depending on clinical presentation, anatomical location, and collaterals involved, SVC obstruction is divided into following grades:

- grade 0 - SVC narrowing without clinical evidence of SVC syndrome;
- grade I - mild to moderate SVC narrowing without collaterals;
- grade II - severe SVC narrowing above the azygos, with the azygos serving as partial collateral;
- grade III - SVC obstruction below the azygos arch;
- grade IV - obstruction at the azygos arch.

**Aortic dissection**

The most common form of acute aortic syndromes and a type of arterial dissection affecting aorta with the formation of a second blood-filled channel (false lumen) within the aortic wall. The majority of cases are seen in elderly hypertensive patients. When imaging a cancer patient - this entity is rather an incidental finding (if not known previously).

Two major classifications systems are used to distinguish different types of aortic dissections, mainly to separate dissections into those that need surgical repair and those that usually require only medical management. The Stanford classification divides dissections by the most proximal involvement: type A - affecting ascending aorta and arch, requiring surgical management (Fig. 10 on page 15, Fig. 11 on page 16); type B - which begins beyond brachiocephalic vessels and may be managed conservatively. The DeBakey classification divides dissections into type I - involving ascending and descending aorta (=Stanford A); type II - involving ascending aorta only (=Stanford A); type III - involving descending aorta only, commencing after the origin of the left subclavian artery (=Stanford B).

Complications of all types of aortic dissections include dissection and occlusion of branch vessels, distal thromboembolism, aneurysmal dilatation and aortic rupture. Stanford A (DeBakey I and II) dissections also may result in coronary artery occlusion, aortic incompetence and rupture into pericardial sac with consequent cardiac tamponade.

**Aortic aneurysm**

Abnormal focal dilatation of an aorta. Divided anatomically into thoracic aortic aneurysms (TAA) and abdominal aorta aneurysms (AAA), the latter are relatively more common.

TAA is most common in 50 to 60-year old age group and the incidence of AAA increases with age, both entities are more common in men. These aneurysms are commonly an incidental finding on
imaging, unless symptomatic or complicated, for example with leak or rupture.

- The most common and feared complication is a rupture with mortality from a ruptured AAA ranging 59-83%. The risk of rupture is proportional to the size of an aneurysm and the rate of growth. When the diameter of TAA reaches 5-6 cm intervention is usually considered as the risk of rupture is significantly elevated, the same strategy is generally accepted for AAAs greater than 5.0 cm in women and 5.5 cm in men.

- FDG uptake in AAA is associated with cellular and molecular alterations prefacing wall deterioration and rupture, may help distinguish inflammatory infiltrate in the aortic wall in contrast to the thrombus in an aneurysm and adds information to suspected mycotic aneurysm diagnosis (Fig. 12 on page 17, Fig. 13 on page 18).

Thoracic conditions

- **Airways obstruction**
  - Malignancies involving the tracheobronchial tree, mediastinum and hilar regions may compress or invade into the central airways, resulting in substantial luminal narrowing.
  - Primary carcinoma of the lung is the most common cause of central airway obstruction. Others include lymphoma, metastatic mediastinal adenopathy, bronchial carcinoid, endobronchial metastases, and primary tracheal tumors such as chondroma and adenoid cystic carcinoma.
  - Combined metabolic and structural data provided by PET/CT is useful for differentiating neoplastic hilar masses from adjacent postobstructive lung parenchymal changes (Fig. 14 on page 18, Fig. 15 on page 19).

- **Lung abscess**
  - A circumscribed collection of pus within the lung. Often complicated to manage and difficult to treat and, in some severe cases, may be life-threatening.
  - In context of cancer patients secondary abscesses are more common and expected, as a result of another condition - first of all, due to bronchial obstruction distal to lung carcinoma (Fig. 16 on page 19, Fig. 17 on page 20) on contrary to primary abscess, which develops as a result of primary infection of the lung (most commonly, from aspiration, necrotising pneumonia or chronic pneumonia).
  - Abscesses vary in size and are generally rounded in shape. May contain only fluid or have a gas-fluid level. Typically there is surrounding consolidation, the wall of an abscess is thick and the luminal surface is irregular.
• FDG uptake is frequently non-specific for differentiation of inflammatory and malignant activity, and an upfront diagnosis based solely on PET data is difficult, but the combination of metabolic and structural data, especially indicating ametabolic/necrotic changes («rim pattern» distribution) with appropriate clinical correlation is useful when secondary lung abscess is suspected in primary lung cancer patient.

Abdominal conditions

• **Bowel obstructions**
  • Acute bowel obstruction, perforation, ischemia, and intussusception are the most common bowel-related emergencies in cancer patients.
  • Advanced gastrointestinal and gynecologic malignancies are the most frequent cause of malignant bowel obstruction. Approximately 10-30% of colorectal carcinoma patients (**Fig. 18** on page 20) and 20-50% of ovarian carcinoma patients may develop acute intestinal obstruction.
  • Both primary and secondary bowel wall neoplasms involving the small intestines and colon can act as a lead point and cause intussusceptions. Neoplastic etiologies are responsible for approximately 50% of all adult intussusceptions ()
  • High-grade obstructions with the rapid development of prominent clinical features («surgical abdomens») are encountered extremely rare on metabolic PET/CT of cancer patients, as these patients are usually referred for imaging with more readily available, quick and simple conventional modalities in such clinical scenario.
  • Nevertheless, a certain portion of metabolic PET/CT exams of patients with known malignancies may contain incidental findings of bowel obstructions caused by neoplasms, especially, low-grade and not clinically prominent obstructions. Cancer patients may also develop bowel obstructions not etiologically connected nor with known malignancy, nor with possible treatment complications, for example - due to hernias or diverticulitis. Timely detection of such conditions may alter patient’s management by warning the clinicians about the possibility of further life-threatening complications development.
  • Feared complications include bowel wall ischemia with subsequent wall necrosis and perforation. Imaging features of such complications include pneumatosis intestinalis (gas in intestinal wall); portal venous gas; pneumoperitoneum in case of bowel perforation; variable amounts of free fluid. It should be noted, that bowel wall thickness is not increased in all causes, and can, in fact, be thinned in complete arterial occlusion or bowel obstruction.

• **Urinary tract obstruction**
• Approximately one-fourth of patients with retroperitoneal and pelvic malignancies may develop urinary tract obstruction.

• Pelvic cancers such as prostate carcinoma, cervical carcinoma (Fig. 20 on page 21), and bladder carcinoma are associated with bladder outlet obstruction. Retroperitoneal malignancies, including lymphoma, sarcoma, and metastatic adenopathy from carcinomas of the cervix, bladder, prostate, rectum, ovary, and testes can cause ureteric obstruction.

• Combined metabolic and structural data provided by PET/CT assists in differentiating of malignant and non-malignant causes of urinary tract obstructions (for example urinary calculi or postinflammatory strictures versus tumor compression or direct invasion).

• Placement of a percutaneous nephrostomy tube or a ureteric stent is the treatment of choice. Confirmation of persistent renal function on the side of the intervention should be considered before any procedure is attempted. Physiologic renal excretion of FDG aids in suspecting of non-functional or preserved renal function.
Fig. 1: Axial images (A-CT component, B-fused image, C-PET component) demonstrating melanoma brain metastasis, with prominent mass-effect, primarily due to large zone of vasogenic edema (arrowheads, A), which causes subfalcine herniation with midline shift towards right and compression of left lateral ventricle (arrow, A). Melanoma metastases are typically highly metabolically avid, and in this case brain metastasis is identifiable even on PET component alone, presenting as hypermetabolic lesion (arrow, C), demonstrating uptake exceeding high physiologic cortex activity.

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Fig. 2: Coronal (A) and axial (B) images of CT component of baseline PET/CT exam of patient with diffuse large B-cell lymphoma (DLBCL), performed for staging purposes, demonstrating enhancing soft tissue component arising from vertebral body and extending both into paravertebral tissues and into the spinal canal, compressing the spinal cord (arrows).
Fig. 3: Images of the same patient (A-MIP PET image, B,C,D - sagittal CT, fused and PET images) demonstrating widespread DLBCL, including bone marrow involvement, with hypermetabolic component extending into spinal canal at the level of thoracic spine. Spine canal involvement may be suspected even on PET images alone, as a hypermetabolic focus extends posteriorly beyond the suppositive line of posterior vertebral bodies margin (arrow, D), which is helpful, especially when low-dose non-enhanced CT is used in PET/CT protocol and soft tissue masses extending from vertebral bodies are visualized less clearly.

Fig. 4: Metabolic PET/CT study of patient with metastatic lung carcinoma, demonstrating widespread hypermetabolic disease (A, MIP PET image) with large right main pulmonary
artery filling defect (B, arrow) representing both metabolically avid and non-avid thrombotic masses (C, fused image).

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**Fig. 5:** Oblique coronal fused PET/CT image (A) of the same patient, showing complex thrombotic masses in right pulmonary artery consisting of metabolically active part from direct tumor invasion (thick arrow) and metabolically inactive portion (thin arrow). Coronal CT image (B) of the same patient demonstrating bilateral iliac veins thrombi (arrows).

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Fig. 6: Images of the same patient with metabolically inactive thrombus (A, arrow) in left pulmonary artery lingular segments branch (A-CT portion,B-fused image) and pulmonary infarctions on the left (C,D) presented with triangular and wedge-shaped consolidations with moderately increased metabolic activity (D, arrows).

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**Fig. 7:** Left subclavian vein thrombosis in a patient with previously treated left breast carcinoma. Coronal images demonstrate filling defect of left subclavian vein (A, arrows) with associated low intensity linear FDG uptake along the course of the vein (C, arrow), suggesting inflammatory reaction (which has consequently resolved after appropriate treatment).

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**Fig. 8:** Combination of reccurent tumor thrombus (A,C, thick arrow) with non-malignant component (C, thin arrow) in inferior vena cava from renal cell carcinoma. Left kidney, affected with large tumor with thrombus extending into inferior vena cava were recently surgically removed (note post surgical changes on the left).

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Fig. 9: Large hypermetabolic mediastinal mass representing recurrent follicular lymphoma causing irregular compression of superior vena cava with almost total occlusion of a short segment of SVS above the azygos - type II SVC obstruction (upper row coronal images, arrow). Also, additional urgent finding in this exam - high volume left sided hydrothorax (lower row, sagittal images with lower lobe total atelectasis (arrows).

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Fig. 10: PET/CT exam of a patient with right lung carcinoma (A, MIP PET image, arrow) demonstrating a Stanford A aortic dissection as an incidental finding (B,C, arrow pointing at the division of true and false lumens).

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**Fig. 11:** Axial images from same exam (A-contrast enhanced CT component, B-non-enhanced CT component, obtained before IV contrast for better lung visualization during breath hold on deep inspiration, C-corresponding PET image). Note the absence of signs of dissection on non-enhanced CT portion and PET image, while contrast enhanced CT image clearly demonstrates aortic arch dissection.

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**Fig. 12:** Coronal images (A-CT component, B-fused images, C-PET component) from PET/CT exam of a patient with lung carcinoma, demonstrating infrarenal abdominal aortic aneurysm (A, arrows). Note no significant corresponding FDG uptake in the AAA to suggest an active inflammatory process.

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Fig. 13: Oblique sagittal thin-slab MIP images of CT component of the same study (A) and corresponding oblique axial images (perpendicular to vessel axis, B and C) at different levels of the aneurysm, measuring 55 mm and demonstrating lower mesenteric artery arising from the aneurysm (C, arrow).

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Fig. 14: Bronchial obstruction due to right lower lobe and hilar neoplastic mass at the level of bronchus intermedius (C, MinIP image, arrow). Combination of metabolic and structural data helps distinguish hypermetabolic neoplastic mass involving right hilum (A, B thick
arrows) and postobstructive middle lobe atelectasis (A,B, thin arrows) demonstrating no significant FDG uptake

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**Fig. 15:** Series of coronal PET/CT images (left to right - CT component, fused images and PET component) demonstrating primary left lung carcinoma arising from and obstructing left main bronchus (upper row, thick arrow) with distal total left lung collapse (upper row, thin arrows) and high-volume hydrothorax (lower row, asterisk) due to malignant pleural involvement (lower row, thick arrows).

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**Fig. 16:** Lung abscess secondary to right lung carcinoma. Coronal PET/CT images (left to right - CT component, fused images and PET component) demonstrate round fluid/ametabolic material collection (thin arrows) with metabolically avid walls («rim pattern» distribution) distal to hypermetabolic neoplastic mass (thick arrow).

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**Fig. 17:** Images from the same study (A-fused image, B-PET component C - MlnIP thick slab sagittal CT component reconstruction) demonstrating fluid-gas level within the abovementioned abscess (A, arrow), no FDG uptake in necrotic material/pus within the abscess (B) and no apparent bronchial drainage of the collection, as bronchi are involved in proximal lung carcinoma (C, arrow).

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Fig. 18: Large bowel obstruction due to rectosigmoid carcinoma. Hypermetabolic mass narrowing and obstructing large bowel lumen (upper row coronal images), with dilated proximal large bowel loops (lower row coronal images). The whole neoplastic conglomerate involved at least two separate bowel loops (C, arrows), «connected» with mesenterial component/adenopathy (C, asterisk).

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Fig. 19: Ileo-ileal intussusception with malignant melanoma metastasis acting as the lead point. Axial CT-component and fused oblique coronal image demonstrate loops presenting with «bowel-within-bowel» appearance with incorporation of adjacent fat (A,C thin arrows). The leading point of intussusception appears to be a hypermetabolic lesion (B, thick arrow), proved to be a melanoma metastasis on consequent surgery 2 weeks after the exam, when patient developed a high-grade bowel obstruction.

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Fig. 20: Right-sided ureterohydronephrosis due to direct ureter compression and invasion by cervical carcinoma. Dilated collecting system of right kidney with delayed and decreased parenchymal enhancement (A, asterisk) and «amputated» dilated distal portion of right ureter (A, arrow) are demonstrated on coronal images, with hypermetabolic cervical mass being the cause of urinary obstruction (B, fused image). Physiologic renal activity and excretion of FDG is preserved (C, PET MIP image).
Conclusion

Metabolic PET/CT performed in oncology patients, though primarily aimed at diagnosis, staging, and restaging of metabolically active malignancies may perform as a tool of detection of the wide spectrum of acute and urgent findings, both caused or related to primary malignant disease and «stand-alone» pathologic conditions. Timely recognition of such findings, especially in outpatient exams, is of high importance.
Personal information

Contact information

Dr. Mykola Novikov,

Department of Diagnostic Radiology, Israeli Oncologic Hospital «LISOD», 27 A. Malyshko Str., Pliuty village, Obukhiv district, Kyiv region 08720, Ukraine

n.novikov@lisod.ua
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