Imaging Patterns of Intratumoral Calcification in the Abdominopelvic Cavity

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Intratumoral calcification is one of the most noticeable radiologic findings. It facilitates detection and provides information important for correctly diagnosing tumors. In the abdominopelvic cavity, a wide variety of tumors have calcifications with various imaging features, though the majority of such calcifications are dystrophic in nature. In this article, we classify the imaging patterns of intratumoral calcification according to number, location, and morphology. Then, we describe commonly-encountered abdominopelvic tumors containing typical calcification patterns, focusing on their differentiable characteristics using the imaging patterns of intratumoral calcification.

Keywords: Abdominopelvic neoplasm; Calcification

INTRODUCTION

Calcification is occasionally observed in tumors, regardless of the organ or type of tumor. It is a notable radiologic feature and one that potentially has clinical significance, since the identification of intratumoral calcification facilitates detection of the tumor as well as its differential diagnosis (1, 2). In the abdominopelvic cavity, various kinds of tumors such as, for instance, mucin-producing tumors, metastases, gastrointestinal tumors, solid pseudopapillary neoplasms (SPNs), and so on are frequently accompanied by intratumoral calcification (2-5). Furthermore, the imaging features of intratumoral calcification also differ according to the type of tumor. However, to date, prior case reports and series regarding intratumoral calcification have each focused on a specific single case or one particular tumor, and no study has addressed this issue comprehensively.

Therefore, in this article, we classify the imaging patterns of intratumoral calcification according to number, location, and morphology of the calcification. In addition, we briefly review the abdominopelvic tumors that frequently exhibit typical patterns of intratumoral calcification. We also describe the imaging features with a focus on the differentiable characteristics of the tumors using the pattern of calcification, together with representative cases.

Intratumoral Calcification and Imaging Modalities

Intratumoral calcification is a type of pathologic calcification. Pathologic calcification is defined as an abnormal calcium deposition in soft tissues. It occurs via
two mechanisms: metastatic and dystrophic. Metastatic calcification may be a result of systemic mineral imbalance, such as uremia or hyperparathyroidism; while dystrophic calcification may be a result of tissue injury, aging, disease, or malignancy (6, 7). Thus, intratumoral calcification is usually considered to be dystrophic calcification caused by degenerative changes of the tissue, such as necrosis or hemorrhage, with the exception of a few bone-forming tumors.

Calcification, as it appears on radiographs and CT images, is easily visible as a hyper-dense or radiopaque lesion, because calcification attenuates X-rays (8). In clinical practice, CT is regarded as the gold standard for the identification of calcified lesions (9, 10).

On US, calcification exhibits a hyperechoic appearance, as it contains high-intensity reflectors. Depending on the size and characteristics of the surface structure of calcification, posterior acoustic shadowing may or may not be evident (8). Occasionally, a color Doppler twinkling artifact (color comet tail artifact) is observed because this artifact is generated by a strongly reflecting medium with a rough interface and because most of the calcifications are small and have a rough surface (11, 12). Therefore, the color Doppler twinkling artifact is a helpful sign for identifying small calcifications and thus can improve diagnostic confidence (12).

On MR, calcification shows various nonspecific signal intensities on conventional spin echo T1- or T2-weighted images (9, 13). Therefore, it difficult to definitively identify the intensities as calcium deposits, and thus small calcifications are easily missed on MR. However, dense calcification typically appears as a signal-void area because it has a very lower water content (8). In a gradient-echo sequence, calcification usually appears as being hypointense and cannot be differentiated from hemorrhage (9).

**Imaging Patterns of Intratumoral Calcification**

To date, a multitude of descriptive expressions have been used unsystematically to describe imaging patterns of calcification: fine, popcorn, granular, punctate, speculated, eggshell, miliary, and so on. We classify several patterns of intratumoral calcification according to the number, location, and morphology of the calcification (Fig. 1). In general, calcification in tumors can be single (solitary) or multiple, and can be located in the peripheral or the central portion of the tumor or at the internal septa. According to its morphology, intratumoral calcification is classified as having patterns which may be punctate (round), amorphous (irregularly shaped), curvilinear (curved line), or rim (eggshell, cyst-wall like appearance).

Then, based on the imaging pattern of intratumoral calcification, we categorize commonly-encountered abdominopelvic tumors which frequently show a typical calcification pattern as follows: mucinous adenocarcinoma, mucinous cystic neoplasm, metastasis, hemangioma, mature cystic teratoma, and miscellaneous tumors.

**Mucinous Adenocarcinoma**

Mucinous adenocarcinoma is a rare subtype (10–15%) of adenocarcinoma that usually occurs in the stomach and the colorectum. It is histologically defined as an extracellular mucin pool of > 50% of the tumor volume (2, 14). Mucinous adenocarcinoma of the stomach shows typical CT findings with a thickening of the diffusely low-attenuating middle or outer layer (corresponding to the mucin pool) and a presence of associated multiple, punctate calcifications (9.5%) (Figs. 2, 3) (15). The presence of mucin is thought to act as an ion-exchange resin, and mucin may be an important factor both for calcium deposition within gastrointestinal carcinoma and in its metastasis (3, 16, 17). Compared with non-mucinous carcinoma, mucinous adenocarcinoma in the colorectum shows more eccentric bowel wall thickening, heterogeneous enhancement, a greater area of low attenuation, and more frequent intratumoral calcification (21%) (2).

![Fig. 1. Imaging patterns of intratumoral calcification according to number, location, and morphology. Calcification is seen—in tumors—in single or multiple form, and can be located in center or peripheral portion of tumor, or at internal septa (septal). Punctate (round), amorphous (irregularly shaped), curvilinear (curved line), or rim (eggshell, cyst-wall like appearance) calcification is in evidence.](image-url)
Mucinous Cystic Neoplasm

Mucinous cystic neoplasm is currently defined as a cyst-forming epithelial neoplasm composed of mucin-producing epithelium and associated with ovarian-type subepithelial stroma (18, 19).

Pancreas

Mucinous cystic neoplasm of the pancreas is a relatively uncommon tumor with a predominance among females (>95%) and a predilection for the pancreas body or tail (20). If mucinous cystic neoplasm is suspected from imaging, complete surgical excision is advocated as the tumor has malignant potential. Mucinous cystic neoplasm from the pancreas shares common clinical and pathologic characteristics with mucinous cystic neoplasm that arises in the liver and ovary (21). On cross-sectional imaging, mucinous cystic neoplasm of the pancreas appears as a well-capsulated, unilocular, macrocystic lesion with or without septation or mural nodule (21-23). Calcification is found in 10–25% of cases with a peripheral, curvilinear pattern or septal location (Figs. 4, 5) (1, 23). Intratumoral calcification occasionally enables differentiation of mucinous cystic neoplasms from serous cystic neoplasms, which frequently have central calcification within the central fibrous scar (1).

Liver

Mucinous cystic neoplasm of the liver is a rare neoplasm of the biliary system and has been previously referred to as biliary cystadenoma and biliary cystadenocarcinoma (18). It occurs usually in the intrahepatic bile duct (85%), and occurs predominantly among middle-aged females (23). On cross-sectional imaging, mucinous cystic neoplasm of the liver appears as a solitary, well-encapsulated cystic...
mass with internal septa and/or mural nodules (23, 24). Intratumoral calcification is rarely found, but was reported in 47% (7/15) of the cases in a recent study (19). It is usually seen within the wall (peripheral) (Fig. 6) and the septa (septal) (Fig. 7) (24). However, calcification can be also seen in intraductal papillary neoplasms and solitary bile duct cysts, which should be differentiated from mucinous cystic neoplasms of the liver (19). Some radiologic features, including the presence of internal septa and solid mural nodules, are more likely to be mucinous cystic neoplasms with invasive carcinoma (biliary cystadenocarcinoma) (25).

Appendix

The descriptive term “mucocele” refers to luminal distension of the appendix by the mucin, regardless of the underlying pathology (26). It can be caused by a variety of non-neoplastic, benign neoplastic, and malignant conditions; however, mucinous neoplasm of the appendix is the most common cause of mucocele (23). The WHO classification recognizes 3 main categories of mucinous neoplasm of the appendix: mucinous adenoma, low-grade mucinous neoplasm, and mucinous adenocarcinoma (27, 28). CT is preferred as the modality of choice because it depicts well the anatomical relationship between the cystic mass and cecum, as well as the tissue characteristics. On CT, an appendiceal mucinous neoplasm appears as a round or tubular cystic mass with an enhancing wall in the expected position of the appendix (Fig. 8) (23). Curvilinear, peripheral (mural) calcification occurs in < 50% of cases (26, 29) (Figs. 8, 9), and it is highly suggestive of the diagnosis. Soft tissue mass, wall thickening, and irregularity raise the suspicion of malignancy (Fig. 9) (28, 30).

Metastasis

Intratumoral calcification is also seen in metastatic lesions. First, some metastases may develop calcifications because of the histology of the primary malignancy. Metastasis from mucinous adenocarcinoma most commonly contains calcification with a punctate pattern, similar to
the primary lesion (3, 17). Metastasis from other primary malignancies such as papillary thyroid cancer, breast cancer, and chondrosarcoma are rare, but may show calcification (Fig. 10) (3).

Secondarily, after systemic chemotherapy or radiation therapy, dystrophic calcification can develop in the metastatic lesion. Calcification in colorectal liver metastasis after chemotherapy is occasionally encountered in clinical practice. Calcification in hepatic metastasis shows a variable pattern and distribution (central and peripheral).

Fig. 7. Mucinous cystic neoplasm of liver, in 75-year-old female.
A. On axial pre-contrast CT image, lobulating, contoured cystic mass is located in segment 7 of liver. Fine septal calcifications (arrowheads) are seen. B. On ultrasound scan, fine septal calcifications (arrowheads), within cystic mass, are seen as echogenic lesions with posterior acoustic shadowing. After hepatic tumorectomy, mucinous cystic neoplasm (biliary cystadenoma) was diagnosed.

Fig. 8. Mucinous neoplasm of appendix in 61-year-old male.
Coronal contrast-enhanced CT image demonstrates cystic dilatation of appendix (asterisk) without evidence of acute inflammation. Curvilinear calcification (arrowhead) is seen at proximal appendiceal wall. Appendectomy was performed, and low-grade appendiceal mucinous neoplasm was diagnosed.

Fig. 9. Mucinous adenocarcinoma of appendix in 72-year-old male.
Axial contrast-enhanced CT image reveals cystic dilatation of appendix (asterisk) with peripheral, curvilinear calcifications (arrowheads). Internal, mild enhancing solid portions and perilisional fatty infiltrations are demonstrated. After appendectomy, mucinous adenocarcinoma was diagnosed.

and may develop or change during therapy (Fig. 11) (31). Calcification in colorectal liver metastasis is generally considered to be a good indicator of the response to treatment (32).

Hemangioma

Hemangioma is a benign vascular tumor and is composed of a blood-filled space lined by single or multiple layers of endothelial cells and a thin fibrous stroma (3). In the abdominal pelvic cavity, hepatic hemangioma is the most common. It has the characteristic imaging features of
Fig. 10. Hepatic metastasis from breast cancer in 60-year-old female.
A, B. Small low-attenuated lesion with tiny calcification (arrowheads) is noted in left lateral section of liver. Metastatic tumor from breast cancer was confirmed via percutaneous biopsy.

Fig. 11. Hepatic metastases from colon cancer in 60-year-old female.
A. Multiple low-attenuated metastases (arrows) are located in both liver lobes on axial contrast-enhanced CT image. B. On follow-up CT image taken after patient underwent chemotherapy, multiple previous metastases are decreased in size, and amorphous intratumoral calcification (arrowhead) is newly developed.

Fig. 12. Hepatic hemangiomas in 67-year-old female.
A, B. There are two small hemangiomas (arrows) in left lobe of liver. On axial pre-contrast CT scan (A), small punctate calcification (arrowhead), known as phlebolith, is seen at small hemangioma (arrows) in left lateral section. Although dynamic contrast-enhanced CT that showed typical progressive centripetal enhancement is not seen, hemangiomas (arrows) show peripheral nodular enhancement and punctate calcification on axial portal venous phase image (B).
a progressive peripheral to central fill-in enhancement pattern on dynamic imaging (33). Calcification is rarely demonstrated in hepatic hemangioma but is often found in sclerosing hemangioma or giant hemangioma (34-36). Calcification in hemangioma is known as a phlebolith, which arises because of thrombosis from inflammation or stasis of blood flow (37). It usually appears as a discrete, rounded pattern (punctate) with a central or peripheral location (Figs. 12, 13) (33-35).

Hemangioma of the gastrointestinal tract is rare, and gastrointestinal bleeding is the most common clinical presentation. Hemangioma may occur anywhere in the gastrointestinal tract; the small bowel is the most frequent site, and the colon is the second most frequent site (38). Most hemangiomas are seen to be pedunculated intraluminal polypoid masses, but occasionally they have an infiltrative submucosal growth pattern (39). In the colon, rectosigmoid is the most commonly involved colonic segment; and colorectal hemangioma shows characteristic imaging features of transmural enhanced bowel wall thickening containing multiple, punctate calcifications (phleboliths) (Fig. 14) (38-40). The presence of multiple, punctate phleboliths is the pathognomonic imaging...

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**Fig. 13.** Mesenteric hemangioma in 47-year-old male. On coronal, maximum-intensity projection CT image, small, round, soft tissue lesion is found in left-sided small bowel mesentery (arrow). Two small punctate calcifications (arrowheads) are seen within lesion. After mass excision, this lesion was confirmed as being mesenteric hemangioma.

**Fig. 14.** Sigmoid colon hemangioma in 22-year-old male. Axial contrast-enhanced CT image demonstrates segmental concentric bowel wall thickening (arrows) with multiple punctate calcifications (arrowheads, phleboliths) involving sigmoid colon. This multiple punctate calcification pattern is characteristic imaging feature of gastrointestinal hemangioma.

**Fig. 15.** Mature cystic teratomas in 40-year-old female. On coronal contrast-enhanced CT image, bilateral ovarian fatty masses containing punctate calcification (arrowheads) are visible. These are pathognomonic radiologic findings of mature cystic teratoma.

**Fig. 16.** Mature cystic teratomas in 55-year-old female. Bilateral mature cystic teratomas are found on axial pre-contrast CT image. In left mature cystic teratoma, presence of peripheral, thick, rim calcification (arrow) and central punctate calcification (arrowhead) are simultaneously noted. Right mature cystic teratoma contains single punctate calcification (arrowhead).
feature of gastrointestinal hemangioma that enables its differentiation from carcinoma (39).

**Mature Cystic Teratoma**

Mature cystic teratoma, also called dermoid cyst, is a cystic tumor of the ovary. The tumor is composed of well-differentiated tissues from at least two of the three germ cell layers (41). Most cases are asymptomatic; however, they can cause acute abdominal symptoms by torsion or rupture of the tumor (42). On CT, fat attenuation within a cyst with or without calcification is diagnostic of mature cystic teratoma (41, 43, 44). Teeth or other calcifications are frequently seen (56%) (44, 45). When bone or teeth are present, they tend to be located within the Rokitansky nodule (41, 46). Thus, intratumoral calcification in mature cystic teratoma usually appears as a single, punctate pattern within the mass (Fig. 15) (41, 47). Occasionally, it is possible to observe unusual dense rim calcification of the cyst wall (Fig. 16) (46-48).

![Fig. 17. Gastrointestinal stromal tumor in 61-year-old male.](image1)

**A.** Exophytic lobulating contoured enhancing mass is seen in stomach high-body greater curvature on coronal contrast-enhanced CT image. Mass contains small, dense punctate calcification (arrowhead) and internal, low-density necrotic portion (asterisk). **B.** On coronal T2-weighted MR image, small dense punctate calcification (arrowhead) is seen as region of hyposignal intensity. Internal necrotic portion (asterisk) within mass appears as region of high signal intensity. Gastrointestinal stromal tumor was confirmed.

![Fig. 18. Solid pseudopapillary neoplasm of pancreas in 28 year-old female.](image2)

**A.** On axial contrast-enhanced CT image, low density mass (asterisk) with thick peripheral, rim calcification (arrowhead) is located in pancreatic tail. Main pancreatic duct is not dilated. **B.** On ultrasound scan, bulging contoured mass (asterisk) is suspected in pancreatic tail. Peripheral, rim calcification (arrowheads) of mass appears as hyperechogenicity with posterior acoustic presentation. Solid pseudopapillary neoplasm was diagnosed after distal pancreatectomy.
Gastrointestinal Stromal Tumor (GIST)

Gastrointestinal stromal tumor (GIST) is the most common primary mesenchymal tumor of the gastrointestinal tract, and arises from the interstitial cell of Cajal (49). Generally, GIST is defined as a KIT (CD117)-positive tumor with a characteristic histologic feature (50). The radiologic appearance of GIST depends on the tumor size: a small GIST is seen as a well-defined mass with homogeneous enhancement, whereas a large GIST is seen as an exophytic heterogeneously enhancing mass with intratumoral hemorrhage or necrosis (49, 51). Calcification in a GIST is unusual (3–10%) and it may occur as a punctate pattern (Fig. 17) (51-53).

Solid Pseudopapillary Neoplasm (SPN)

Solid pseudopapillary neoplasms is a rare neoplasm of the pancreas that typically occurs in young females (54). The characteristic finding of SPN is a large, solitary, well-encapsulated mass with varying amounts of intratumoral hemorrhage or cystic component (55, 56). Intratumoral calcification is occasionally associated with SPN; and a peripheral curvilinear, rim (eggshell), or punctate pattern is usually seen (Fig. 18) (5).

Pancreatic Neuroendocrine Tumor (PNET)

Pancreatic neuroendocrine tumor (PNET) is a rare pancreatic neoplasm which demonstrates neuroendocrine differentiation (57). It is classified as functioning or non-

Fig. 19. Pancreatic neuroendocrine tumor in 54-year-old female.
A. On axial contrast-enhanced CT image, large lobulating contoured hypervascular mass (asterisk) is located in pancreatic tail. Lesion contains multiple amorphous calcifications (arrows and arrowheads) at central and peripheral portions of mass. B. On contrast-enhanced T1-weighted image, dense calcifications (arrowheads) appear as dark signal intensity at center of mass (asterisk). However, other peripheral amorphous calcifications (arrows on A) are not clearly visualized. This mass was confirmed as neuroendocrine tumor (grade 2) after distal pancreatectomy.

Fig. 20. Multiple schwannomas in 39-year-old female. Coronal contrast-enhanced CT image demonstrates multiple round masses (asterisks) in retroperitoneum, which are confirmed as schwannomas. Punctate and curvilinear calcifications (arrowheads) are seen in some tumors.
functioning by hormonogenesis, and non-functional tumors currently account for the majority of newly diagnostic PNETs (up to 60–80%) (58). On imaging, a functioning PNET is typically found as a small (1–2 cm) hypervascular mass, whereas a non-functioning PNET appears as a relatively larger heterogeneous mass and commonly contains calcification, necrosis, or cystic change (59, 60). Calcification is found in approximately 20% (30/133) of them, and large tumors were more likely to be associated with calcification regardless of whether they are either functioning or non-functioning tumors (61). The pattern of calcification is very diverse and includes punctate, coarse (amorphous), and multiple pattern (Fig. 19) (60, 62). Calcification has often been thought to be indicative of a malignant lesion (58, 62). A recent study, however, found no significant correlation between the calcification and tumor grade (63). Intratumoral calcification can be helpful in differentiating PNET from pancreatic adenocarcinoma, because only 2% of adenocarcinomas show calcification as compared with 20% of PNETs (64).

**Neurogenic Tumors**

Neurogenic tumor is classified into ganglion cell origin (e.g., neuroblastoma, usually in children), paraganglionic system origin (e.g., pheochromocytoma, paraganglioma), and nerve sheath origin (e.g., neurilemmoma, so called schwannoma) (65). In the abdominal cavity, the tumor usually occurs in the retroperitoneum or the adrenal gland. It commonly appears as a well-circumscribed, smooth, or lobulating mass. Calcification may be seen in all types of neurogenic tumors with various patterns (Fig. 20) (65).

**Castleman Disease**

Castleman disease is an uncommon, benign lymphoproliferative disorder characterized by hyperplasia of the lymphoid follicles (66). Approximately 70% of cases are located in the thorax; 10–15% in the neck; and 10–15% in the abdomen, retroperitoneum, and pelvis (67, 68). Castleman disease commonly presents as single, well-circumscribed enhancing mass of varying locations in the abdomen and pelvis. Intratumoral calcification is reported in up to 31% (5/16) of cases of Castleman disease of the abdomen and pelvis (69). A variety of calcification patterns including punctate, peripheral, central, and arborizing patterns can be seen (Fig. 21) (66, 69). The presence of calcification may help in differentiating Castleman disease from lymphoma, since calcification would be rare in untreated lymphoma (70).

**CONCLUSION**

Intratumoral calcification exhibits various imaging patterns in various types of abdominopelvic tumors. However, several commonly-encountered tumors have a tendency towards showing typical patterns of intratumoral calcification. Although a specific diagnosis of a precise kind of tumor may not always be possible using only intratumoral calcification, imaging patterns of intratumoral calcification can help to facilitate accurate diagnosis and improve diagnostic confidence with regards to abdominopelvic
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tumors. Therefore, it is useful to be aware of, and to be familiar with, the imaging patterns of intratumoral calcification in abdominopelvic tumors.

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