The Radiology of Abdominal Calcification Including Demonstration of a Readily Useful and Comprehensive Classification Scheme

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The analysis of abdominal calcifications and other radiopacities on plain radiographs is often a diagnostic challenge. Occasionally, historical information will be of value; at times, physical examination will contribute important clues. Laboratory date such as the presence of microscopic hematuria will sometimes be helpful. Yet, very frequently, the appearance of the opacity is unexpected. Since the plain film is, in most cases, the first radiologic examination of the abdomen, there is often no further information available to the radiologist. Hence, the decision whether to proceed with further workup rests on an evaluation of the nature of the calcification.

While the literature abounds in short articles and case reports describing specific entities, little has been written about a systematic assessment of abdominal radiopacities. Careful attention to morphology, location, and mobility can narrow the diagnostic possibilities considerably. In most instances, the position and pattern of the calcification can be fairly well established even before contrast studies are performed. An analysis of the details of the appearance of the density and awareness of its relationship to other structures can often reveal its identify on plain films.

Morphology

The formation of a classification of abdominal calcifications is difficult. The designated criteria of a particular group may be too general to be applied to a specific example or too detailed for practical implementation. Consequently, there has been no prior attempt to propose a comprehensive morphological classification of abdominal calcifications. Rather the emphasis has been on the demonstration of the uniqueness of a number of individual pathologic entities. For example, the term "staghorn," a vivid description of a renal calcullus occupying the calyceal system, serves to differentiate the appearance of that stone from other abdominal radiodensities. However, only a very few calcifications are so easily identifiable.

Features of value for the classification of the morphology of calcifications include shape, border sharpness, marginal continuity, and internal architecture. An evaluation of these factors permits a grouping of abdominal calcification into four discrete morphological groupings, each possessing a set of features peculiar to itself. The four categories are concretions, conduit wall calcification, cyst wall calcification, and solid mass calcification. In the following discussion, this categoization scheme will be discussed in detail. Mention will also be made of potential pitfalls and notable exceptions.

Concretions

A concretion is a calcified mass formed in the lumen of a vessel or hollow viscus. Concretions can be faint or brightly calcified; the radiographic density depends on the size of the opacity and the amount of calcium per unit volume. Although there are many sites in which concretions may form, the most common are the pelvic veins, the gallbladder, and the urinary tract. Concretions can be formed by the precipitation of calcium salts, as in renal calculi, or by the deposition of calcium in pre-existing venous thrombi with the development of phleboliths. Prostatic calculi occur predominantly in the elderly whereas appendicoliths are usually encountered in younger patients. With some concretions, such as pancreatic stones, inflammation seems to play a role, but for others, such as enteroliths, the reasons for formation are more obscure. Hence, concretions do not share a common etiology.

Moreover, concretions do not have a common shape. Small stones tend to be round or oval. Multiple gallstones are frequently faceted and multiple urinary stones, especially in a dilated system, may also be faceted on at least one side of their perimeter. Ureteral calculi are often angular but bladder calculi are usually smooth. Occasionally, specific diagnostic forms also occur, such as the star-shaped bladder calculus.

Most stones exhibit a sharp, clearly defined external border, but on occasion, concretions may have irregular bulges. Concretions are calcified throughout the entirety of their circumference. Almost always there are no discontinuities in the external margin. This is an important feature, especially if the interior of the concretion is lucent, because it helps to distinguish large stones from calcified cysts. If the outer ring of calcification is not complete, it is unlikely to be a stone.

The internal architecture of concretions is varied. They can be homogeneously dense, a pattern frequently encountered in urinary calculi. They may have a central or slightly eccentric lucency, an appearance which is characteristic of many plebol iths. Multiple laminations indicate concretion morphology unequivocally. Alternating bands of encircling lucency may be found within a concretion or there may be a single lucent band close to the external rim. Annular laminations are frequently encountered in gallstones, vesical calculi, and appendicoliths.

Each of the various internal patterns is quite distinctive. Laminations have a predictable parallel appearance. For the most part, central lucencies are single. When there is only a marginal rim of calcification, the width of the rim is continuous and usually of minimally varying thickness throughout the circumference. The inner pattern of stones is hardly ever mottled, whorled, or patchy. Rarely, calcifications will deposit on only one surface of a stone, and on plain radiographs, a streaky or amorphous focus of calcification will be seen. These exceptions aside, the vast majority of stones will exhibit geometric outlines and continuous contours.

Stones form within the lumen of pre-existent structures. Unlike cysts or solid lesions, which are pathologic masses that distort or displace normal organs, stones tend to remain within vessels or hollow viscera. If multiple calcific densities appear to be arrayed in line, this suggests a common location in a hollow tube. Infrequently, concretions are found outside expected locations, such as gallstones in the ileum or colon, an appendicolith in the peritoneal cavity, or multiple phleboliths in a hemangioma. Generally, however, concretions do not pass through vascular or visceral walls, and are seen in association with anatomic structures.

Conduit Wall Calcification

Conduits are hollow tubes through which fluids pass. In the abdomen, conduits include the biliary ductal system, the components of the urinary tract, pancreatic ducts, the vas deferens, and arteries and veins. The majority of conduit wall calcifications in the abdomen involve the aorta and its branches. The tubular appearance of conduits can easily be appreciated if the calcification is encircling. En face, a ringlike density will be seen. Unlike concretions, discontinuities of the opaque ring are not unusual. Since calcifications in conduit walls are not uniform, unopacified and radiodense areas are irregularly arrayed along the course of a vessel. However, calcification is confined only to the tubular walls. The presence of internal radiopacity suggests another morphologic category.

Because calcium deposition can occur throughout the circumference of a conduit, when the x-ray beam is directed perpendicular to the vessel, the wall having the greatest thickness will appear most densely calcified. Thus, in profile, conduit wall calcification presents as parallel tracks of increased density. Splenic artery calcification often appears as calcified tracks describing a serpiginous path. Although less common, a branching pattern is also characteristic of many vascular calcifications. This can be seen at the bifurcation of the abdominal aorta and in intrarenal arteries. When a vessel of narrow caliber is densely calcified, a stringlike appearance may be noted. In female pelves, horizontal, slightly undulating opaque lines of density often represent uterine artery calfication.

However, conduit wall calcification is not always so obvious. When there is only a single fleck of calcification, differentiation from a small calculus or from cortical bone can be difficult. This is especially true when it occurs in the region of the renal pelvis. Often the question arises whether a linear density signifies calcification of the renal artery or the lateral margin of a vertebral transverse process. Inasmuch as calcification within the vessel wall is not homogeneous, the margins of a focal density may be irregular and the border indistinct. Also, conduit wall calcifications are found close to the expected location of a vessel. Hence, it would be very unusual for conduit calcifications to be located at the lateral margins of the liver or spleen or in other peripheral locations.

Cyst Wall Calcification

For this discussion, a cyst will be considered to be any abnormal fluid-filled mass. Included in this category are the epithelial-lined true cysts, pseudocysts which have a fibrous integument, and spherical and ovoid aneurysms. Although cysts are of various types with different histologic appearances and etiologies, they share, when calcified, common radiograph features that permit diagnosis on plain films. Of all the morphological categories, cyst wall calcification is the least variable and the easiest to recognize. Critical for cyst pattern recognition is the presence of a smooth curvilinear rim of calcification. Very small cysts rarely calcify so that, when roentgeno- graphically visible, cysts have a diameter larger than any nearby conduit. Although arcuate linear radiopacities are seen in both conduits and cyst wall calcification, the calcific rim of the cyst usually has a larger diameter than that of a concuit. Yet, the calcific rim need not be complete. At times, only a portion of the wall is radiodense. This is in sharp distinction to concretions, where a complete rim of calcifications is a hallmark. Moreover, since cysts usually have only one encircling wall, they are rarely laminated. An incompletely calcificed single rim clearly indicates the presence of a cystic density, rather than a concretion.

Cysts are not always exquisitely round. They may be oval or compressed on one side and appear asymmetric. The shape of a cyst depends in great measure on its location. Cysts can distort and displace organs or vessels, or they can be delimited by adjacent solid structures. Most cysts present only with rim calcification. Occasionally there appears to be central, calcification occurring when calcium deposition is so extensive that even surfaces which are not tangential to the x-ray beam are sufficiently dense to be visible. In such an instance, the "interior" of a heavily calcified cyst has an indistinct, smudgy appearance, less radiopaque than the wall.

Sometimes it is difficult to differentiate calcification in cyst walls from that of solid masses. The outer surface of a cyst is usually smooth, whereas the transition between the inner surface of a calcific rim and the liquid material contained within it may be indistinct and roughened. In solid mass calcification the outer margin of opacity is often ill-defined. In general, the calcific rim of cysts is well-demarcated and arcuate, whereas in solid densities, curvilinear calcification is usually irregular. However, occasionally leiomyoma of the uterus will have smooth linear calcification at its margin and may simulate cystic calcification.

The cystic pattern of calcification can be found anywhere in the abdomen. A peripheral density is unlikely to be a concretion or conduit, a spatial restriction that does not apply to a cyst. The most common abnormalities with the radiographic appearance of the cystic type are aneurysms of the abdominal aorta and of the splenic artery, both seen frequently in the elderly. Aortic aneurysm is often associated with conduit calcification in the contiguous aorta and iliac vessels. Splenic artery aneurysms frequently occur in conjunction with calcification in adjacent portions of the splenic artery. Cystic calcifications related to the genitourinary tract include renal cysts, (about 5 percent calcify), renal artery and intrarenal aneurysms, echinococcal cysts, old perirenal hematomas, multicystic kidney (occasionally calcify in adults), parapelvic cysts, and adrenal cysts. On occasion, solid neoplasms (most often benign adenoma) of the kidney and adrenal show calcification simulating that of cyst walls. In North America calcified splenic and hepatic cysts are much less frequent than calcified renal cysts, whereas in other parts of the world (e.g., the Mediterranean Basin and the Middle East) calcified cysts of the spleen and liver are common because of the high incidence of echinococcus infestation. Retroperitoneal tumors such as pheochromocytomas may assume a cystic appearance. In the lower abdomen, calcified cysts are more rare. Some of the entities found in this location are calcified mesenteric cysts, calcified mucoceles of the appendix, and calcified benign cystic lesions in the ovary.

Solid Mass Calcification

The fourth category, solid mass calcification, is the most diverse in terms of radiologic appearance, yet in almost all cases can be identified by an irregular calcified border and a complex inner architecture. Solid masses may appear as mottled densities, with scattered radiolucencies within a calcified background. Calcified lymph nodes often present in this way. A whorled pattern with incomplete bands and arcs of calcification around ill-defined lucent foci is frequently seen in uterine leiomyoma. Irregular streaks and flecks of radiodensity may occupy the substance of a mass. Another common pattern is flocculent calcification superimposed on a lucent background. No matter how dissimilar the interior pattern, solid calcifications share this unifying feature - the inner architecture is nongeometric. There is no monotony or regularity in the distribution of calcium deposition detectable on plain films of the abdomen. In most instances, the interior calcification is more prominent than the marginal calcification. Frequently, the calcification does not extend to the edge of the mass, and the outer aspect of solid mass densities may be discontinuous, making the contours of calcium deposition irregular. At times, the mass contains separate islands of amorphous calcification. Occasionally, the border of a solid mass is more densely calcified than the interior. Although such an appearance resembles cystic calcification, the margins are rarely smoothly curvilinear; rather they may appear crenated or slightly angulated.

Like cysts, solid masses can appear anywhere in the abdomen. They may be central or peripheral, adjacent to or within organs, in the retroperitoneal or intraeritoneal spaces. Most common are calcified mesenteric lymph nodes, which can occur anywhere along a broad arc extending from the left upper quadrant to the right lower quadrant of the abdomen along the course of the small bowel mesentery. They can be multiple and of varied sizes. Tuberculous infection has been invoked as the cause of these calcifications, but in the majority there is no other evidence of intra-abdominal granulomatous infection.

In women, the most frequent calcified solid mass in the pelvis is a uterine leiomyoma. They are often multiple and may attain great size. They need not be confined to the pelvis, but can be seen almost anywhere in the abdomen. Usually, leiomyomas have a whorled type of calcification, but occasionally a prominent bordering rim of calcification may be seen. Solid mass calcification can occur in renal malignancies, adenomas, and hamartomas. Tuberculous and chronic abscesses in the kidney may also calcify. Solid calcification in the substance of the spleen is uncommon and pancreatic mass calcification is very rare. More frequent, but still distinctly uncommon, are calcified metastatic deposits in the liver. Benign and primary malignant hepatic neoplasms with calcified foci are rare, as are tumors in the hollow organs of the genitourinary tract. Occasionally, adrenal adenomas or carcinomas may present as a calcified mass, other solid retroperitoneal tumors seldom calcify.

Psammomatous calcification is a type of solid calcification that is so distinctive that it merits separate consideration. Psammoma bodies are small calcified concretions that occur intracellularly within the substance of ovarian serous cystadenocarcinomas. Because individual calcifications are microscopic, they cannot be appreciated as distinct entities on a radiograph. Only masses of psammoma bodies, if sufficiently calcified and numerous, can be detected. When faint, psammomatous calcification is seen as a poorly localized, finely granular pattern. However, when dense, the calcification may be so intense that other structures will be obliterated if they are overlain by the mass. Psammomatous calcification appears as a cloudlike conglomeration without internal lucency or distinct borders. It may occur in the primary lesion or in metastatic deposits in the peritoneal cavity, the liver, and retroperitoneal lymph nodes. Carcinoma of the stomach, colon, gallbladder, or liver may present with amorphous calcification on plain radiographs which is indistinguishable from psammomatous calcification. However, in these malignancies, the calcification is found in extracellular mucin formed by the tumor and also in sites of hemorrhage and necrosis.

Caveats

The classification of abdominal calcifications according to radiographic morphology can help in the analysis of an unknown opacity. However, there are several limitations that need to be emphasized When a calcification is very small, it is difficult, if not impossible, to categorize. If it is too minute to have an inner pattern or definable contour, morphological analysis is not feasible. For example, a single fleck of calcification could represent a small stone, a segment of an artery, a section of the wall of a cyst, or a part of a solid lesion. Similarly, very faint calcification cannot be classified if no information about margins or center can be ascertained.

The distinction between solid mass calcification and ossification may sometimes be difficult. Ossified structures contain trabeculae, which appear as long thin strands of radiodensity oriented along a straight line or smooth arc. Parallel trabeculae are usually of equal width, as contrasted with the varying width and direction of solid mass calcifications. If a cortex having a thickened rim with smooth external and internal margins can be recognized, the presence of bone is established. Dermoid cysts in the ovary are common pelvic masses in young women. Many times calcified teeth are observable within the lesion. Generally, there is no difficulty in differentiating between a calculus in the distal ureter and a tooth in a dermoid cyst. Sometimes, however, the two densities may resemble each other and proper identification can rest on the relationship of the calcification to an accompanying mass. Teeth are present within or at the margins of the dermoid cyst whereas stones will either be unassociated with a soft tissue mass or deviated away from it.

Occasionally, there are calcifications with appearances reflecting the characteristics of more than one morphological type. Calcification in the wall of the gallbladder is not rare; occasionally it may look like a single large gallstone. However, gallbladder wall calcification usually has a dense rim of variable width and may be discontinuously radiopaque, unlike large gallstones which almost always calcify uninterruptedly throughout their perimeter. Sometimes it is not clear if a group of calcific densities consist of multiple stones or a large mass. Pancreatic stones are often dissimilar in size and configuration. They can appear to extend diffusely without evidence of placement within a closed space even though they are within pancreatic ducts. In contrast, in a typical collection of gallstones, there is no confusion with solid mass calcification because the calculi are similar in size and shape and are seen to be clearly delineated within a hollow structure. Some solid masses may have only marginal calcifications and this may look exactly like cysts. While these examples point out the possible pitfalls apparent in this classification scheme, in most cases it is still possible to ascribe a specific abdominal calcification to one of the four major categories with a reasonable measure of assurance.

Mobility

The movement of abdominal radiopacities, either during one examination or over a period of time, provides additional information and can lead to a plain film diagnosis. Gravity, respiration, peristaltic activity, and the growth of masses can all cause changes in the position of abdominal densities. An aid in the detection of calculi within a fluid medium is the recognition of layering in an upright position. With the x-ray beam directed horizontally, stratification of freely moving calcified concretions in a liquid medium can be observed. This is most often noted with gallbladder stones and calculi in hydronephrotic sacs. Very striking is the layering in milk of calcium, most common in the gallbladder, but potentially observable in any other hollow structures in the abdomen which has an alkaline pH permitting the precipitation of calcium salts.

Radiopacities that are free in the peritoneal caaavity demonstrate great mobility. These are rare, but their marked change in position on sequential films permits recognition. Mesenteric calcifications also exhibit movement but to a lesser extent than free intrperitoneal densities. However, calcifications trapped in fixed solid organs do not move In contrast, calcifications within fluid-filled structures, such as the lumen of the gastrointestinal tract, the pelvicalyceal system of custs are apt to migrate along the direction of flow.

Effect of Respiration

Alternations is position with respiration may help to distinguish retroperitoneal densities from intraperitoneal masse. Retroperitoneal calcifications are usualy fixed and do not change significantly with phase of respiration. Intraperitoneal calcifications, especially in the upper abdomen, may be displaced by the excursion of the diaphragm. Also, costal cartilage and soft tissue calcifications in the upper abdomen move with the ribs and thus will be at different locations in inspiration and expiration.

Effect of Peristalsis

The migration of urinary calculi on successive examinations is frequently observed. This is due to propulsion toward the bladder by ureteral contractions and the flow of urine. Similarly, peristaltic activity in the intestinal tract can cause movement of intraluminal densities.

Growth of Masses

The growth of calcium-containing masses can be evaluated by the change in the position of a radiodensity on serial radiographic studies. The size of aortic aneurysms can be ascertained by the separation of calcifications in the anterior wall of the vessel from the vertebral body on lateral films. Any increase in this distance suggests enlargement of the aneurysm. The growth of noncalcified masses may be evaluated by displacement of adjacent fixed calcifixcdensities. Phleboliths will move very little in the pelvis, except when pushed by an adjacent mass. The "phlebolith displacement" sign is a neglected but a valuable aid in the detection of enlarging pelvic masses and cysts.

Finally, the mobility of abdominal calcification may be the result of processes not fully explainable by the effects of gravity, respiration, peristalsis, or local enlargement. Gallstone ileus is an intestinal obstruction caused by a gallbladder calculus that has eroded through the gallbladder wall usually to the duodenum and then progressed through the lumen of the small bowel only to be restricted by the caliber of the terminal ileum, or by narrowings in the large intestine. The initial observation of a right upper quadrant calculus and the later demonstration of the same calculus in the pelvis and left lower quadrant points to this possibility. The associated radiographic findings of air in the biliary tree and small bowel obstruction assure the diagnosis.

Conclusion

An abdominal calcification can often be identified after an evaluation of its morphology, location and mobility. This approach is advantageous because it allows a determination to be made from the information provided from plain films alone. At the very least, close inspection of the characteristics of an abdominal radiodensity will narrow the diagnostic possibilities considerably and will direct further workup to the appropriate confirming studies.

Reference

Baker SR, Elkin MS. Plain Film Approach to Abdominal Calcifications. Saunders, Philadelphia, 1983, Chapter 1, pp. 1-25.