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MDCT Diagnosis of Perineural Invasion Involving the Celiac Plexus in Intrahepatic Cholangiocarcinoma: Preliminary Observations and Clinical Implications

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OBJECTIVE. The purpose of this study was to test the hypothesis that soft-tissue infiltration along the celiac plexus and delayed enhancement exceeding two-thirds of the tumor area on preoperative MDCT correlate with histologic evidence of perineural invasion in resected intrahepatic cholangiocarcinomas.

MATERIALS AND METHODS. Two experienced abdominal radiologists retrospectively reviewed preoperative multiphasic MDCT scans of 20 patients who underwent resection of intrahepatic cholangiocarcinoma, identifying soft-tissue infiltration along the celiac plexus, delayed enhancement exceeding two-thirds of the tumor area, and maximum tumor diameter. Consensus findings were compared with intratumoral perineural invasion in resected intrahepatic cholangiocarcinomas using the Fisher exact test.

RESULTS. Six patients had histologic intratumoral perineural invasion, five of whom had soft-tissue infiltration along the celiac plexus on preoperative MDCT, with corresponding 83.3% sensitivity and 92.9% specificity for perineural invasion and significant association between these MDCT and histologic findings ($p = 0.002$). No patients with histologic perineural invasion had enhancement exceeding two-thirds of the tumor area on MDCT; sensitivity was 0.0% for this finding. Tumor diameter on MDCT was not significantly associated with perineural invasion at histopathology ($p = 0.530$).

CONCLUSION. Soft-tissue infiltration along the celiac plexus on MDCT is an indicator of perineural invasion in patients with intrahepatic cholangiocarcinoma. The data did not confirm an association between delayed enhancement exceeding two-thirds of the tumor area and perineural invasion. Because perineural invasion from intrahepatic cholangiocarcinoma is associated with a very poor prognosis and is generally a contraindication to surgery, the MDCT diagnosis of celiac plexus perineural invasion in patients with intrahepatic cholangiocarcinoma may have important implications for prognosis and treatment planning.

Keywords: bile duct neoplasms, cholangiocarcinoma, liver neoplasms, MDCT, neoplasm staging

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Intrahepatic cholangiocarcinoma accounts for 10–15% of primary liver malignancies and is second in incidence to only hepatocellular carcinoma [1–3]. Although a relatively rare tumor, the global incidence of intrahepatic cholangiocarcinoma appears to be steadily rising [2, 4, 5]. Intrahepatic cholangiocarcinoma has a very poor prognosis, with a 5-year survival rate of less than 5–10% for unresectable disease [4]. For patients with resectable disease, surgery offers the only potential cure; even with surgery, however, the 5-year survival and 5-year recurrence-free survival rates are only about 30% and less than 40%, respectively [1, 2]. Although localized nodal or perineural metastases immediately adjacent to the intrahepatic tumor within either the gastrohepatic or hepatoduodenal ligament can potentially be resected with negative margins, nodal or perineural metastases involving the celiac plexus are generally considered to be contraindications for attempted curative hepatic resection [1, 2].

Multiple prognostic factors have been described that predict overall survival or recurrence-free survival in intrahepatic cholangiocarcinoma [1, 6–8]. Perineural invasion is seen at histopathology in up to 80% of patients with intrahepatic cholangiocarcinoma, is a known marker of very aggressive disease, and is associated with a poor prognosis [1, 3, 8, 9]. Perineural invasion is a process different from metastasis via the bloodstream or lymphatic system, with distinctive histologic features, underlying cellular mechanisms, and molecular mediators [9].

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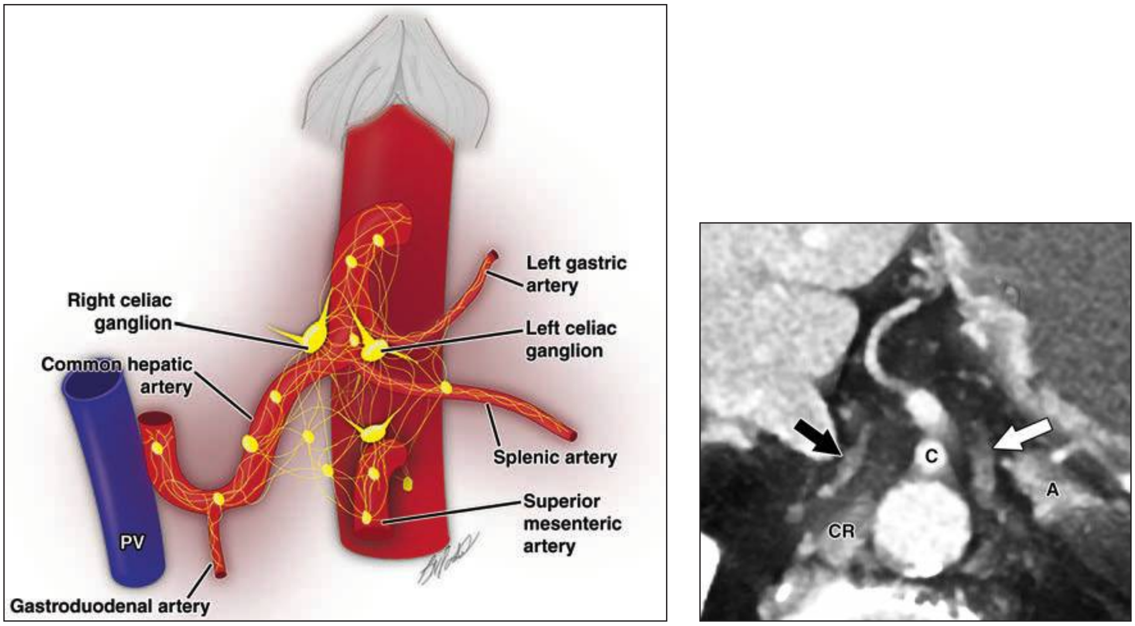

A B

Fig. 1—Anatomy of celiac plexus.
A, Anatomic drawing of celiac plexus shows celiac ganglia and extensive network of autonomic nerve fascicles surrounding celiac artery and its branches [15, 16, 18, 26]. Gastroduodenal artery, splenic artery, left gastric artery, and celiac artery are contiguously invested with fascicles of celiac plexus. Dissemination of hepatic tumors can occur within perineural space of celiac plexus, with right hepatic lobe tumors extending via autonomic nerve fibers coursing along common hepatic artery within hepatoduodenal ligament and left hepatic lobe tumors extending via autonomic nerve fibers coursing along neural plexus of left gastric artery within gastrohepatic ligament. For context, perineural plexus associated with superior mesenteric artery and corresponding mesenteric ganglion is also shown. PV = portal vein. (Drawing by Patel BN)
B, 70-year-old woman with intrahepatic cholangiocarcinoma who had true-negative findings on preoperative MDCT. Three-dimensional axial volume-rendered small-FOV preoperative MDCT image shows normal celiac ganglia as thin, discoid soft-tissue structures (*arrows*) adjacent to celiac artery (C) with no abnormal soft-tissue infiltration along celiac artery. Also visible are left adrenal (A) and right crus of diaphragm (CR).

Preoperative imaging plays a key role in the diagnosis and staging of intrahepatic cholangiocarcinoma, and the MDCT findings of intrahepatic cholangiocarcinoma itself have been well studied [10–13]. However, to our knowledge, little has been published about the MDCT appearance of perineural invasion associated with intrahepatic cholangiocarcinoma and its possible involvement of perihepatic neural plexuses. Anatomically, the liver and biliary tree are richly innervated by autonomic nerve fibers of the celiac plexus that access the liver along major hepatic arteries as neurovascular bundles within the hepatoduodenal ligament and gastrohepatic ligament [14] (Fig. 1). Extrahepatic tumor spread from intrahepatic cholangiocarcinoma can extend in a retrograde fashion along neural fascicles of the celiac plexus, invading within the perineural space of these nerve fascicles traversing the hepatoduodenal or gastrohepatic ligaments, to ultimately reach the celiac plexus at the base of the celiac artery and the adjacent celiac ganglia [8].

Prior reports have shown that preoperative MDCT may be useful in diagnosing perineural invasion involving the celiac plexus in patients with extrapancreatic spread of pancreatic adenocarcinoma [15–18]. We hypothesized that preoperative MDCT might similarly be useful for identifying perineural invasion in patients with intrahepatic cholangiocarcinoma, also showing soft-tissue infiltration of the celiac plexus along the celiac artery. Additionally, we sought to validate the observation of Asayama et al. [19], who found that, in 32 patients with intrahepatic cholangiocarcinoma, enhancement of greater than two-thirds of the primary lesion on delayed phase images was associated with histologic evidence of perineural invasion. We therefore sought to retrospectively compare preoperative MDCT evidence of celiac plexus infiltration and delayed enhancement exceeding two-thirds of the primary tumor area with the presence or absence of intratumoral perineural invasion on histologic examination of resected intrahepatic cholangiocarcinomas.

Materials and Methods

This HIPAA-compliant study received approval from our institutional review board, and the need for informed consent was waived given its retrospective design. We considered the preoperative contrast-enhanced MDCT scans and postoperative pathology reports in all patients with intrahepatic cholangiocarcinoma who underwent hepatic resection at our institution over the 4-year period from January 2010 to January 2014.

Patients

Using an electronic database, we identified patients within the study period who had received a diagnosis of intrahepatic cholangiocarcinoma, had undergone preoperative multiphase MDCT before resection of intrahepatic cholangiocarcinoma, and had undergone delayed phase imaging at 3 minutes after contrast injection as a component of their preoperative MDCT. Twenty patients were thus identified whose MDCT images and pathology reports were then reviewed.

MDCT Technique

All patients underwent preoperative contrast-enhanced 64-MDCT (LightSpeed VCT, GE Healthcare; or Somatom Sensation 64, Siemens Healthcare) performed as standard clinical examinations. Of these 20 patients, 14 underwent triphasic MDCT

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Fig. 2—72-year-old woman with intrahepatic cholangiocarcinoma who had true-negative findings on preoperative MDCT for perineural invasion. Histologic examination of resected intrahepatic cholangiocarcinoma confirmed no perineural invasion.
A, Arterial phase axial MDCT image shows left hepatic lobe intrahepatic cholangiocarcinoma (*arrow*) with enhancing hypervascular rim and adjacent transient hepatic attenuation difference.
B, More caudal arterial phase axial MDCT image shows normal fat planes around celiac artery (C) without abnormal periceliac artery soft-tissue infiltration. Note normal bilateral celiac ganglia (*arrows*). Also visible are left adrenal (A) and right crus of diaphragm (CR).

with breath-held acquisitions obtained at 30–45 seconds (arterial phase), 60–70 seconds (portal venous phase), and 3 minutes (delayed phase) after contrast injection. The remaining six patients underwent biphasic MDCT with two breath-hold acquisitions obtained at 60–70 seconds (portal venous phase) and 3 minutes (delayed phase) after contrast injection. Patients undergoing biphasic studies were those without prior clinical suspicion of intrahepatic cholangiocarcinoma.

All patients received 150 mL of 370 mg I/mL nonionic contrast medium (Isovue 370, Bracco Diagnostics) injected at either 4 mL/s (for triphasic studies) or 2.5 mL/s (for biphasic studies). The axial slice thickness varied from 0.625 to 1.0 mm for 19 patients; for one patient, 5-mm slice thickness was used for both portal venous and delayed phase images. The axial image data were routinely reconstructed to produce coronal and sagittal images and, when deemed helpful, 3D volume-rendered images of the celiac artery.

MDCT Image Review

The preoperative MDCT image sets (axial, coronal, and sagittal) were reviewed by two radiologists, each with more than 25 years of experience in abdominal imaging. The reviewers were blinded to the postoperative histopathology reports and were thus blinded to the presence or absence of histologic evidence of perineural invasion. The diagnosis of intrahepatic cholangiocarcinoma itself was known to the reviewers. MDCT results were based on the consensus of the two radiologists.

MDCT diagnosis of celiac plexus perineural invasion—Perineural invasion involving the celiac plexus was diagnosed on MDCT when contiguous soft-tissue infiltration was noted extending from the intrahepatic tumor directly along one of two known extrahepatic perineural pathways to ultimately involve the fat planes around the celiac artery. These two perineural pathways include the neural plexus along the left gastric artery within the gastrohepatic ligament (for left hepatic lobe tumors) and the neural plexus along the common hepatic artery within the hepatoduodenal ligament (for either right hepatic lobe or Couinaud segment 4B tumors) [20]. Perineural invasion was considered not to be present on MDCT when the fat planes around the celiac artery were normal.

Lymph node metastasis also can occur around the celiac artery and within the perihepatic ligaments but is a different biologic process from perineural invasion [9]. We specifically sought to differentiate lymphadenopathy from perineural invasion on MDCT. Perineural invasion was diagnosed on MDCT when plaquelike soft-tissue infiltration was seen to extend contiguously from the intrahepatic tumor along a known extrahepatic neural pathway to involve the celiac plexus at the base of the celiac artery. Nodal disease was identified on MDCT when discrete discontinuous rounded or oval soft-tissue nodules were noted surrounded by fat.

Assessment of delayed enhancement—The proportion of tumor enhancing on delayed phase images was assessed visually on the axial images showing the largest transverse extent of each intrahepatic cholangiocarcinoma, using the method previously described by Asayama et al. [19]. Enhancing regions were defined as those with attenuation greater than that of the nearby liver on contrast-enhanced images and were visually scored as either occupying greater than two-thirds of the tumor area or not occupying greater than two-thirds of the tumor area.

Assessment of tumor size—To evaluate the possibility that perineural invasion could simply be associated with larger, more advanced tumors, we defined tumor size as the maximum diameter of each primary lesion on portal venous phase MDCT images. Portal venous phase images were used for this purpose because they were available for all patients, are free from the transient hepatic attenuation differences of the arterial phase, and provide maximal background hepatic parenchymal enhancement [21, 22].

Histologic Examination

Each resected intrahepatic cholangiocarcinoma specimen was examined histologically, and the final histopathology reports in the electronic medical record were reviewed retrospectively to establish the presence or absence of intratumoral perineural invasion. These reviews were performed by individuals other than the radiologists who reviewed the images. H and E–stained histologic sections routinely were prepared from surgical specimens, and slides were examined for perineural invasion by an attending pathologist. Specimens included resected hepatic parenchyma and immediately adjacent tissues. Periceliac artery tissues were not typically available and thus were not included. Perineural invasion was defined as the presence of neoplastic cells within the epineurium, perineurium, or endoneurial space [9].

Statistical Analysis

With respect to soft-tissue infiltration along the celiac artery, preoperative MDCT scans were counted as true- or false-positive for perineural invasion when patients exhibited this MDCT finding and respectively did or did not have perineural invasion on histologic examination of resected specimens; preoperative MDCT scans were counted as true- or false-negative for perineural invasion when patients did not exhibit this MDCT finding and respectively did not or did have perineural invasion on histologic examination of resected specimens. With respect to tumor enhancement that exceeded two-thirds of the tumor area on delayed MDCT images, true- or false-positive and -negative MDCT scans were defined in the same fashion, likewise using histologic examination as the reference standard. The possibility that sex-based differences could exist with respect to perineural invasion was evaluated using the sex specified in each patient's imaging examination.

Results were evaluated using the unpaired two-tailed t test for comparisons of means, the exact binomial test to establish 95% CIs for fractional

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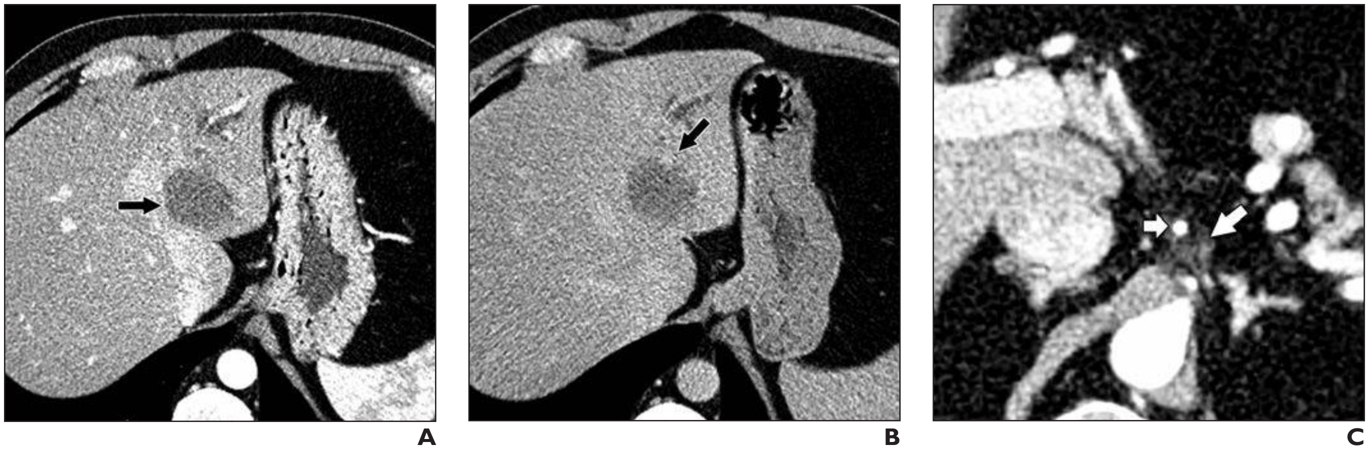

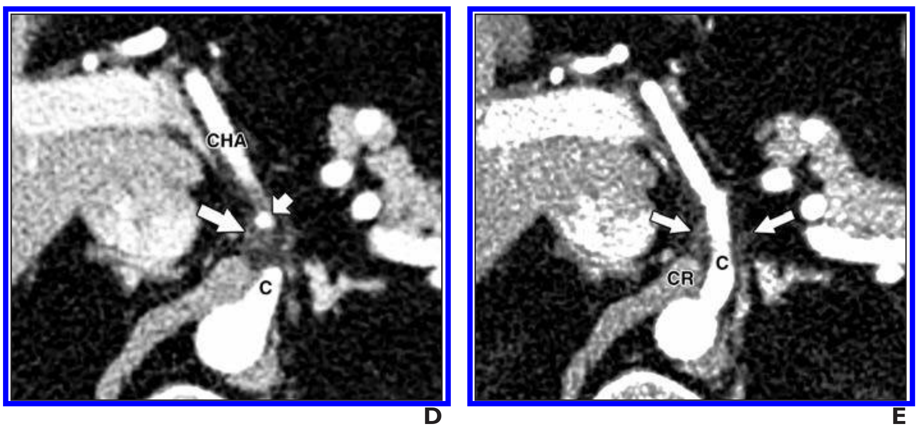

Fig. 3—51-year-old man with left hepatic lobe intrahepatic cholangiocarcinoma who had true-positive findings on preoperative MDCT for perineural invasion, with soft-tissue infiltration around celiac artery and little enhancement of primary tumor on delayed phase imaging.
A, Arterial phase axial MDCT image shows left hepatic lobe intrahepatic cholangiocarcinoma (*arrow*).
B, Three-minute delayed axial MDCT image shows small region of nodular enhancement (*arrow*) within intrahepatic cholangiocarcinoma. Enhancement does not exceed two-thirds of area of lesion.
C, Arterial phase axial MDCT image shows soft-tissue infiltration (*long arrow*) within gastrohepatic ligament along left gastric artery (*short arrow*).
D, More caudal arterial phase axial MDCT image shows perineural invasion infiltrating celiac plexus (*long arrow*) near origin of celiac artery (C). Also visible are common hepatic artery (CHA) and left gastric artery (*short arrow*).
E, Slightly more caudal arterial phase axial MDCT image shows soft-tissue infiltration (*arrows*) around celiac artery (C). Also visible is right crus of diaphragm (CR).

TABLE 1: Twenty Patients With Intrahepatic Cholangiocarcinoma Who Underwent Preoperative MDCT and Subsequent Surgical Resection, Stratified by Sex, Preoperative MDCT Evidence of Soft-Tissue Infiltration Along the Celiac Artery, and Histologic Intratumoral Perineural Invasion

		Soft-Tissue Infiltration Along Celiac Artery on Preoperative MDCT		
Observation	Total	Present	Absent	p[a]
Patients	20	6	14	1.000
Men	12	4	8	
Women	8	2	6	
Perineural invasion[b]				0.002
Present	6	5	1	
Absent	14	1	13	

Note—Except where otherwise indicated, data are no. of patients.
[a]By Fisher exact test.
[b]At histopathology of resected specimens.

values, and the Fisher exact test for comparisons of proportions. All analyses were performed using the Stata (version 12.1, StataCorp) statistical platform. Evaluations with p values less than 0.05 were considered statistically significant.

Results

The 20 patients with intrahepatic cholangiocarcinoma in our study included 12 men (age at resection: range, 45.2–80.6 years; mean, 63.5 years) and eight women (age at resection: range, 42.9–79.5 years; mean, 62.1 years) ($p = 0.800$). Preoperative MDCT did not show soft-tissue infiltration along the celiac artery in 14 of these 20 patients (Fig. 2) and did show such infiltration in the remaining six patients (Figs. 3 and 4). Some patients with infiltration along the celiac artery also exhibited recognizable infiltration along first-order celiac artery branches such as the left gastric artery and the common hepatic artery (Figs. 3 and 4). Histologic examination of surgical specimens revealed intratumoral perineural invasion in six patients, including five of the six with soft-tissue infiltration along the celiac artery on MDCT and one of the 14 without such infiltration on MDCT (Fig. 4E). No significant association with sex was evident with respect to whether patients did or did not exhibit soft-tissue infiltration along the celiac artery on MDCT ($p = 1.000$) (Table 1).

Soft-tissue infiltration along the celiac artery on preoperative MDCT was significantly associated with histologic evidence of perineural invasion, confirming this aspect of the original hypothesis ($p = 0.002$) (Table 1). The true-positive, false-positive, true-negative, and false-negative results for this MDCT finding, using histologic examination as the reference standard, numbered 5, 1, 13, and 1, respectively (Table 1), with corresponding sensitivity, specificity, positive predictive value, negative predic-

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tive value, and accuracy of 83.3% (95% CI, 35.9–99.6%), 92.9% (66.1–99.8%), 83.3% (35.9–99.6%), 92.9 (66.1–99.8%), and 90.0% (68.3–98.8%), respectively.

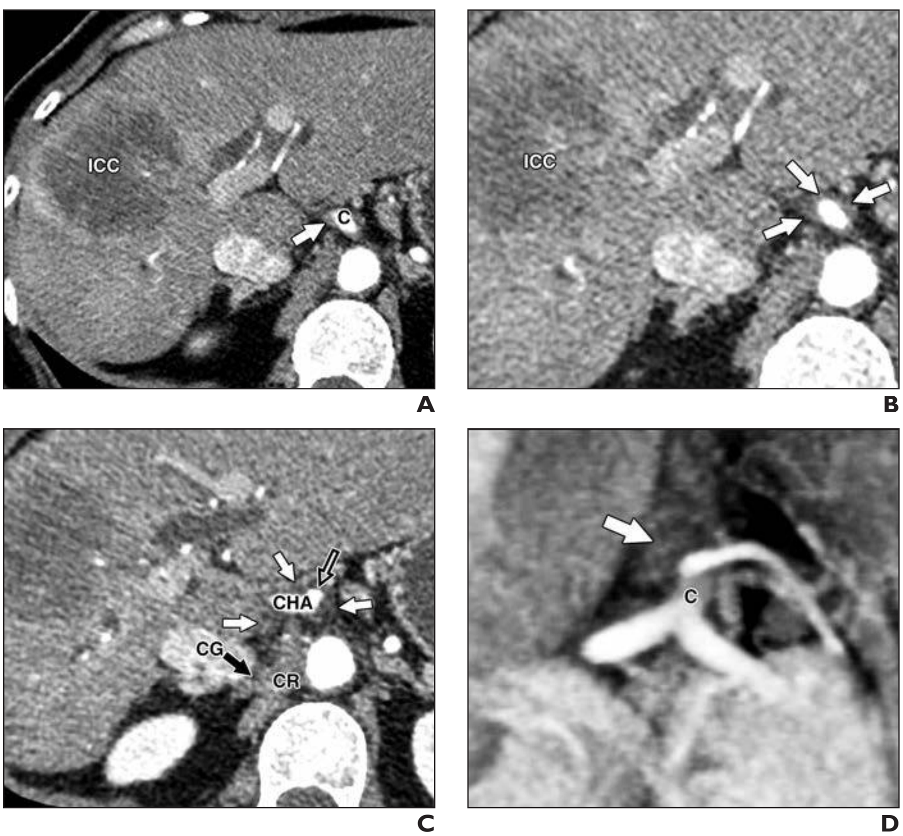
None of the six patients with histologic evidence of perineural invasion had enhancement greater than two-thirds of the tumor area on delayed MDCT images (Fig. 3), whereas seven of the 14 patients without perineural invasion did. Although these findings yielded a significant association with findings at histopathology ($p = 0.051$), the sensitivity and positive predictive value were quite low; the true-positive, false-positive, true-negative, and false-negative results numbered 0, 7, 7, and 6, respectively, with corresponding sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of 0.0% (0.0–45.9%), 50.0% (23.0–77.0%), 0.0% (0.0–41.0%), 53.8% (25.1–80.8%), and 35.0% (15.4–59.2%).

Mean tumor size was compared between patients with and patients without histologic evidence of perineural invasion. No significant association was found between these two groups, with mean maximum tumor diameters of 4.6 and 5.2 cm, respectively ($p = 0.530$).

Discussion

Perineural invasion is a commonly observed histologic finding in biliary malignancies, including intrahepatic cholangiocarcinoma, and is likely a major factor contributing to the overall poor survival [6–8]. Localized nodal or perineural metastasis adjacent to intrahepatic cholangiocarcinoma within either the gastrohepatic or the hepatoduodenal ligament is potentially resectable with negative surgical margins [1, 2]. However, metastasis to the celiac nodes or perineural invasion to the celiac plexus is generally a negative prognostic factor, contraindicating major hepatic resection with curative intent. The ability to preoperatively diagnose celiac plexus perineural invasion with MDCT could therefore have a significant impact on prognosis, treatment planning, and the selection of patients for whom surgery is appropriate.

Intrahepatic cholangiocarcinoma has been well characterized on contrast-enhanced MDCT as a focal hypodense mass with irregular peripheral rim enhancement on arterial phase and portal venous phase images and gradual centripetal enhancement, resulting in hyperenhancement on delayed phase images [10–13]. However, the appearance on MDCT of perineural invasion associated with intrahepatic cholangiocarcinoma has not been emphasized in the literature, to our knowledge. The celiac plexus is an extensive network of autonomic nerve fibers coursing along the celiac artery and its branches, innervating most of the digestive tract, including the hepatobiliary system [14]. The bilateral celiac ganglia are enmeshed in the center of the celiac plexus, are the anatomically densest components of the plexus, and form the superior extent of the plexus. The celiac ganglia are usually well appreciated on MDCT as discoid or multilobulated



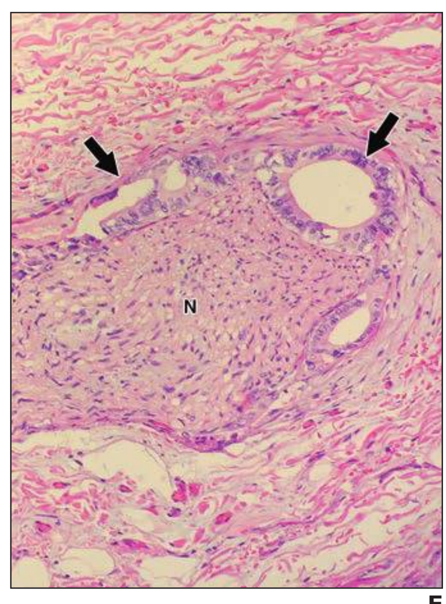


Fig. 4—51-year-old woman with right hepatic lobe intrahepatic cholangiocarcinoma who had true-positive findings on preoperative MDCT for perineural invasion. Histologic examination of resected intrahepatic cholangiocarcinoma revealed perineural invasion.
A, Arterial phase axial MDCT image shows intrahepatic cholangiocarcinoma (ICC) with peripheral rim enhancement in right hepatic lobe. Note soft-tissue infiltration (*arrow*) around celiac artery (C).
B, Slightly more caudal axial arterial phase MDCT image again shows soft-tissue infiltration (*arrows*) of intrahepatic cholangiocarcinoma (ICC) around celiac artery.
C, Even more caudal axial arterial phase MDCT shows extensive soft-tissue infiltration (*white arrows*) around proximal splenic artery (*open arrow*) and common hepatic artery (CHA). Note thickening of right celiac ganglion (CG and *black arrow*), highly consistent with perineural invasion. Also visible is right crus of diaphragm (CR).
D, Coronal volume-rendered arterial phase MDCT image shows thickened right celiac ganglion (*arrow*) near celiac artery (C). Branches of celiac artery are visible (left gastric artery, originating superiorly; common hepatic artery, coursing toward patient's right; and splenic artery, coursing toward patient's left).
E, Photomicrograph (H and E, ×200) shows neoplastic glands of cholangiocarcinoma (*arrows*) invading perineural space of nerve (N) near hepatoduodenal ligament.

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structures with characteristic retroperitoneal locations at the level of the celiac and superior mesenteric arteries, medial to the adrenal glands, and anterior to the diaphragmatic crura [23]. Given that intratumoral perineural invasion is a frequent histologic finding in resected intrahepatic cholangiocarcinoma specimens and that the hepatobiliary system is innervated by the celiac plexus [14], we postulated that intrahepatic cholangiocarcinoma could extend along known perineural pathways in the fashion of pancreatic adenocarcinoma [15].

In our cohort of 20 patients with intrahepatic cholangiocarcinoma, soft-tissue infiltration along the celiac plexus on preoperative contrast-enhanced MDCT was significantly associated with histologic perineural invasion in resected surgical specimens ($p = 0.002$), resulting in specificity of 83.3%, sensitivity of 92.9%, and accuracy of 90.0%. These preliminary findings suggest that MDCT is useful in diagnosing perineural invasion in the setting of intrahepatic cholangiocarcinoma. Tumor diameter was not significantly different between patients with and patients without perineural invasion, suggesting that tumor size alone is not responsible for these observations. Recent genomic analysis of intrahepatic cholangiocarcinoma has shown a strong association between perineural invasion and K-ras mutations [24]. Thus, the genomic subtype of intrahepatic cholangiocarcinoma may be of greater importance in prognosis than is tumor size. Additionally, we postulated that patients with evidence of perineural invasion on MDCT are more likely than others to have the K-ras mutation.

On the basis of these results, we speculate that the observed soft-tissue infiltration around the celiac artery on MDCT represents extrahepatic perineural extension or metastasis in the presence of intrahepatic cholangiocarcinoma. Because periceliac tissues are not typically obtained during the resection of intrahepatic cholangiocarcinomas [25], this remains a speculative point that has not been supported or refuted by histologic evidence, to our knowledge. Periceliac artery lymph nodes are sampled in extended lymph node dissections for some individuals with intrahepatic cholangiocarcinoma [25]; however, such cases are infrequent at our institution and typically provide only lymphoid tissue for histologic analysis.

In our series of 20 patients, we were not able to confirm the observation of Asayama et al. [19] that delayed enhancement exceeding two-thirds of the tumor area is significantly associated with perineural invasion. In 32 patients, Asayama et al. found that this correlated significantly with perineural invasion as well as with the extent of scirrhous stromal desmoplasia and, on multivariate analysis, with reduced survival. Although we found an association at the borderline of significance between such enhancement and histologic perineural invasion ($p = 0.051$), our results included sensitivity of 0.0%; none of our patients with histologic evidence of perineural invasion had this degree of delayed enhancement, whereas half of those without perineural invasion did. It is possible that none of our 20 patients' tumors were of the scirrhous type found by Asayama et al. to exhibit this proportion of delayed enhancement; at our institution, the proportion of tumor that is scirrhous is not typically reported. Additionally, it may be that the smaller number of patients in our series, the different nature of CT in the two studies (MDCT in our study vs predominately single-detector CT in the study by Asayama et al.), or the somewhat different timing of delayed phase imaging (3 minutes in the current study vs 4–6 minutes in the study by Asayama et al.) contributed to the different findings. Larger clinical studies with pathologic correlation may help to clarify this point.

Given the particularly poor prognosis of intrahepatic cholangiocarcinoma when perineural invasion is present [1, 3, 8], the preoperative diagnosis of perineural invasion by MDCT may be helpful in patients with intrahepatic cholangiocarcinoma for staging, determination of prognosis, and treatment planning and may assist with decisions regarding neoadjuvant therapy, adjuvant therapy, and hepatic resection. Further to this, we speculate that soft-tissue infiltration around the celiac artery on MDCT could be biopsied before undertaking a major resection, either via endoscopic ultrasound guidance or at the time of laparotomy, providing tissue with which to further evaluate the presence or absence of perineural invasion.

There were several limitations to our study. Patients with intrahepatic cholangiocarcinoma who have undergone surgical resection are uncommon, and this is reflected by our small sample size despite the 4-year period during which patients were accrued. Because this was an early feasibility study and because the number of cases with histologically proven perineural invasion was small, the study was not designed to address interobserver agreement. In addition to the issues investigated, we initially attempted to examine potential correlations between our preoperative MDCT findings and subsequent postoperative survival (data not presented here); however, we found that long-term data were not available for many of our patients; thus, such correlations remain an important topic for future prospective studies. Finally, because periceliac tissue is not routinely resected at intrahepatic cholangiocarcinoma surgery, we do not have specimens with which to show unequivocally that the soft-tissue infiltration around the celiac artery on MDCT is in fact perineural invasion.

In summary, soft-tissue infiltration along the celiac plexus on preoperative MDCT correlated well with histologic evidence of intratumoral perineural invasion in resected specimens of intrahepatic cholangiocarcinoma, supporting the first portion of our hypothesis with reasonably high sensitivity and specificity (83.3% and 92.9%, respectively). Delayed enhancement involving greater than two-thirds of the tumor area, however, did not significantly correlate with intratumoral perineural invasion in our series. Further studies will be required to more extensively explore correlations between preoperative MDCT findings and the behavior of intrahepatic cholangiocarcinoma as well as the potential correlations between MDCT findings and genomic data. We hope that this early study will stimulate further investigation into the potential uses of MDCT to benefit patients with this challenging disease.

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