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Celiac Plexus Cryoneurolysis

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Abstract

Intractable, chronic abdominal pain from upper abdominal malignant and benign diseases is a significant challenge for healthcare providers and burden on the healthcare system. While opioid analgesics are commonly used to provide pain relief, the adverse effects of chronic opioid use cannot be overlooked. Celiac plexus neurolysis via chemical or thermal means represents an alternative minimally invasive approach to provide palliative pain relief and increase patients' quality of life. Through the use of computed tomography guidance, celiac plexus neurolysis can be performed by accurately targeting the celiac plexus, while minimizing risks to adjacent structures. Historically, celiac plexus neurolysis was performed via instillation of ethanol or phenol; however, within the past decade cryoablation has gained increasing use with potentially fewer side effects.

Keywords
- celiac plexus
- malignancy
- cryoablation
- neurolysis
- pain management
- interventional radiology

Upper abdominal malignancies including pancreatic, hepatobiliary, and gastrointestinal cancers can cause severe abdominal pain, adversely affecting patients' quality of life and survival.[1,2] The mechanism of pain induction can be from direct tissue damage (nociceptive), or compression/invasion of the nervous system (neuropathic).[3] The management of cancer-related pain involves a multidisciplinary approach including analgesic medications, image-guided neurolytic interventions, and surgery. Opioid analgesic medications are frequently used to alleviate pain in this patient population at the risk of opioid dependence and adverse side effects related to this class of pharmacotherapy. While surgery would address the underlying cause of the pain, many patients are not candidates for surgical resection due to advanced stage of the cancer or comorbidities. Targeting the nerves carrying the pain signals using image guidance represents a minimally invasive approach in alleviating pain in these patients.[4]

The nociceptive signals from the abdominal viscera are carried by the splanchnic nerves that are relayed to the celiac plexus (CP).[5] Disruption of this nociceptive neural pathway at the level of the CP can result in alleviation of pain.[6] The means by which this disruption can be achieved is referred to as neurolysis which is destruction of the plexus achieved by chemical (phenol or ethanol) or thermal (heat or cold) means. CP neurolysis is performed with computed tomography (CT) guidance, which provides a safe and precise targeting while minimizing risk to nearby structures.[7]

Anatomy of Celiac Plexus

The CP comprises a network of ganglia located at the anterolateral aspect of the aorta between the celiac axis and superior mesenteric artery (SMA) at the T12–L1 level. This consists of predominantly preganglionic sympathetic efferent nerve fibers, derived from the greater splanchnic (T5–T9), lesser splanchnic (T10–T11), and least splanchnic (T12) nerves.[7] The CP relays preganglionic sympathetic and parasympathetic efferent fibers to and visceral sensory afferent fibers from upper abdominal viscera. The transmission of nociceptive impulses from the liver, gallbladder, pancreas, spleen, adrenal glands, kidneys, stomach, and distal esophagus to the distal transverse colon occur via the visceral sensory afferent fibers.[8]

The CP can frequently be identified on abdominal CT given the technical advances in multidetector CT technology. On

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axial CT images, the ganglion often demonstrates a discoid or lobulated configuration that resembles the limbs of the adjacent adrenal gland and diaphragmatic crus.[9] The right celiac ganglion is often located between the inferior vena cava (IVC) and right diaphragmatic crus, anteromedial to the medial limb of the right adrenal gland. Zhang et al[10] described the location of the right celiac ganglion as residing just posterior to the angle formed by the right renal vein as it enters the IVC. The left celiac ganglion is consistently seen just medial and inferior to the medial limb of the left adrenal gland and lateral to the left diaphragmatic crus. The three-dimensional configuration of the plexus drapes along the anterolateral region of the aorta between the celiac axis and SMA.

Patient Selection and Technical Approach

Patients who would benefit from CP neurolysis include those with intractable abdominal pain from pancreatic, hepatobiliary, and upper gastrointestinal malignancies, as well as those with hepatic metastasis or malignancies metastasizing via the retroperitoneal lymph nodes.[11] In addition, patients with chronic abdominal pain from chronic pancreatitis may benefit from CP neurolysis.[12] Contraindications for CP neurolysis include uncorrectable coagulopathy, local or intra-abdominal infection, and bowel obstruction.[7] There are several approaches to access the CP when performing neurolysis. Imaging modality, patient position, needle location, and laterality are dependent on the mechanism of neurolysis, operator preference and comfort, and anatomic considerations. Anatomic factors include patient's body habitus, amount of retroperitoneal fat, adjacent structures, and degree of tumor infiltration in the setting of abdominal malignancy. Anterior and posterior approaches are commonly chosen using CT guidance; however, percutaneous ultrasound, endoscopic ultrasound, and fluoroscopic guidance have also been described.[8] In the anterior approach, a needle is inserted through the abdominal wall directly anterior to the level of the CP. In this approach, various abdominal structures including the stomach, small bowel, liver, and pancreas are traversed with a small-caliber needle, which is generally tolerated.[8] The posterior approach requires prone positioning with usually two needles inserted bilaterally through the paraspinous musculature into the region of the CP via an antecrural position. Although this approach often necessitates the placement of two needles, takes slightly more time, and requires the patient to lie prone, ganglia targeting is usually more accurate and selective due to precise placement into the nerve plexus and avoids traversal of abdominal organs (►**Fig. 1**). CT guidance is also able to accurately depict anatomic variations of the celiac trunk or regional distortion, which can result from tumor spread.[13] Another key benefit of CT is the ability to depict the extent of spread of the neurolytic agent within the antecrural space via a test injection with dilute contrast (►**Fig. 2**). This allows for evaluation of any inadvertent injection of contrast mixture into adjacent structures or leakage into the peritoneal cavity.[13] In addition, alternative mechanisms of neurolysis (e.g., thermal ablation) can be safely performed using CT, taking advantage of precise targeting, direct ablation zone visualization, and less procedure-related pain when compared with chemical agents.[14]

History of CP Chemical Neurolysis

Traditional agents used to achieve permanent neurolysis of the CP include ethanol and phenol. Ethanol works through immediate precipitation of endoneural lipoproteins and mucoproteins within nerve ganglia, leading to leakage of cholesterol, phospholipid, and cerebroside from the neurilemma.[13,15] At an ethanol concentration above 50%, irreversible damage to neurons occurs, and the degree of destruction is dependent on the distribution of ethanol within the CP.[13] Ethanol has been known to cause significant transient pain upon injection, and as a result some interventionalists recommend adding a long-acting local anesthetic such as bupivacaine to the ethanol cocktail to achieve injection-related pain control.[7] Very dilute iodinated contrast material (1 mL of iodinated contrast media in 30–50 mL normal saline) has also been recommended to help visualize the intended distribution of ethanol prior to injecting the chemical neurolytic agent.[7,13] Given the frequent use of general anesthesia to assist with blood pressure lability during the procedure, our institutional preference is to administer 20 mL of pure 100% ethanol through bilaterally placed 22-gauge Chiba needles through a posterior approach (a total of 40 mL 100% ethanol) after a test injection of diluted contrast.

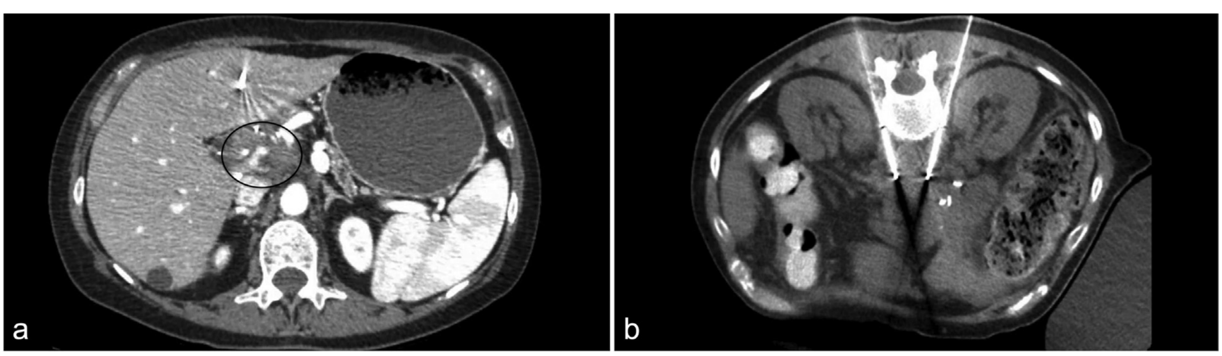

Fig. 1 CT-guided celiac plexus cryoneurolysis in a patient with pancreatic cancer. (**a**) Contrast-enhanced CT demonstrating pancreatic head malignancy (black circle). (**b**) Intraprocedural CT images demonstrate two cryoprobes positioned through a posterior approach in the antecrural position.

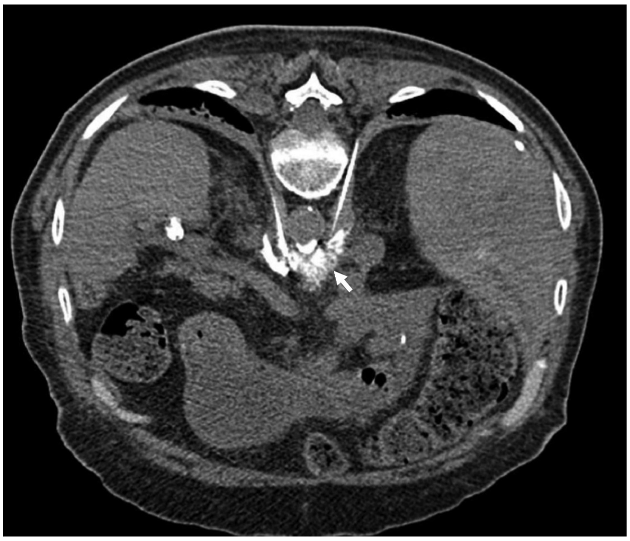

Fig. 2 CT-guided alcohol celiac plexus neurolysis in a patient with metastatic pancreatic cancer. An intraprocedural noncontrast CT image through the celiac plexus demonstrates test injection (prior to alcohol injection) via bilateral 22-gauge Chiba needles of dilute iodinated contrast (small white arrow) with appropriate dispersion in the expected location of the celiac plexus.

Fig. 3 CT-guided celiac plexus cryoneurolysis in a patient with gastric carcinoma and intractable upper abdominal pain. An intraprocedural noncontrast CT image demonstrating posterior antecrural placement of bilateral cryoablation probes just lateral to the aorta between the celiac axis and SMA origins. The ablation zones (ice balls marked by the small white arrows) are localized to the expected location of the celiac plexus with selective targeting of the nerve bundle at that level.

Technical Approach for CP Cryoneurolysis

As outlined earlier, the patient is placed in the prone position on the CT table and a scout CT is performed without contrast. The initial scan is reviewed to confirm an adequate window for placement of bilateral cryoablation probes to the level of the CP. Intermittent CT guidance is used to guide each needle to its proper position taking extreme care to avoid transgression of any adjacent structure (►**Fig. 3**). CT imaging also allows for precise needle placement and visualization of the cryoablation zone (i.e., ice ball) encompassing the CP. In comparison to chemical neurolysis, contrast injection prior to the treatment is not required or performed. Once the two cryoablation probes are in appropriate position, two 10-minute freeze, 5-minute passive thaw cycles are performed with intermittent CT images to monitor the ablation zone.

Strict hemodynamic monitoring is an important consideration when performing CP cryoneurolysis. Patients can experience significant hypotension from decreased sympathetic tone that results in vasodilatation and low cardiac output.[13,16] To mitigate the risk for significant intraprocedural hypotension, patients are often given supplement fluid replacement prior to the procedure with intravenous fluid and albumin to “tank up” the circulating blood volume to adequate levels. In addition, an arterial line can be a helpful adjunct for real-time hemodynamic monitoring if available. This allows for dynamic and timely correction, as systolic pressures can often change dramatically from the freeze portion of the cycle to the passive thaw.

Advantages of CT-Guided CP Cryoneurolysis

Chemical neurolysis of the CP using ethanol is well studied and is an effective agent for means of pain palliation in the setting of painful pancreatic adenocarcinoma.[17] The potential adverse side effects related to ethanol injection include nontarget distribution, transient intractable diarrhea, cardioneurologic dysfunction, blood pressure lability, bleeding, or a combination of these sequela. Retrospective data demonstrate a lower incidence of diarrhea and fewer gastrointestinal side effects with CP cryoablation compared with ethanol.[18] Chemical CP neurolysis is also limited by bulky infiltrative tumors that can impede the dissemination and distribution of injected fluid, often rendering the procedure less effective and necessitating repeat interventions.[17]

As previously alluded to, CT guidance has emerged as a favorable modality for CP neurolysis due to its precise targeting, real-time monitoring of needle placement, and utility in employing more advanced ablative techniques such as thermal ablation.[17] CT-guided cryoneurolysis was first reported by Yarmohammadi et al,[19] in which nine patients with pancreatic adenocarcinoma successfully underwent the procedure with only one minor complication. In patients with bulky tumor disease, retroperitoneal lymph nodes, or who have failed prior ethanol neurolysis, CT-guided cryoneurolysis may be the preferred treatment versus a chemical neurolytic agent.[17]

Conclusion

CP neurolysis is a safe and effective intervention for palliative pain management in patients with intractable abdominal pain due to malignant and benign etiologies. CT guidance allows for selective nerve ganglia targeting with controlled neurolysis via chemical or thermal ablation. Recent global initiatives in addressing the opiate crisis and providing patients additional options for pain control have sparked interest in alternative forms of pain management. In patients with upper abdominal malignancies, CP neurolysis is effective in both eliminating the source of intractable abdominal pain and mitigating the adverse effects of opioid analgesics.[20]

Conflict of Interest
None declared.

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