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Gastric lymph node contouring atlas: A tool to aid in clinical target volume definition in 3-dimensional treatment planning for gastric cancer

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Abstract

Purpose: To develop a contouring atlas of the gastric lymph node stations to be used in defining and planning clinical target volumes in 3-dimensional treatment planning for gastric cancers.

Methods and Materials: Four physicians, including 2 radiation oncologists, a diagnostic radiologist, and a surgical oncologist specialized in gastric cancer, convened over the course of multiple meetings. Four patients were identified as representative cases, including 3 gastric cancer patients treated with differing surgical approaches (total gastrectomy, Ivor-Lewis esophagogastrectomy, and distal gastrectomy) and 1 patient with intact gastric anatomy. Radiographic delineation of lymph node stations was established for each case to highlight differences between intact anatomy and different postoperative anatomy.

Results: Consensus was achieved among physicians in order to create a computed tomographicbased contouring atlas of gastric lymph node stations. Detailed radiographic lymph node station delineation for both intact gastric anatomy and post-surgical anatomy are discussed.

Conclusions: This report serves as a template for the delineation of gastric lymph node stations to aid in the definition of elective clinical target volumes to be used in conformal treatment planning. Published by Elsevier Inc. on behalf of American Society for Radiation Oncology.

Introduction

Supplementary material for this article (http://dx.doi.org/10.1016/j. prro.2012.03.007) can be found at www.practicalradonc.org.

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For patients with resectable gastric adenocarcinoma, locoregional recurrence remains a significant pattern of failure, and may occur as a component in up to 80%-85% of failures after surgery alone.¹ In 2001, the Gastric Surgical Adjuvant Trial Intergroup 0116 established the role of adjuvant chemoradiation therapy in the treatment of high risk, completely resected adenocarcinoma of the

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stomach and gastroesophageal junction.² However, the study also highlighted the difficulty in defining appropriate radiation fields. Approximately one-third of patients had major or minor protocol violations, including violations due to risk of producing major treatment-related morbidity or failing to cover high-risk regions.²

In order to standardize treatment fields, a consensus statement published by Smalley et al³ subsequently sought to define field placement based on the anatomic relationship between target tumor volumes. With treatment fields conducted mostly in the era of 2-dimensional planning, commonly involving anterior-posterior opposed fields, INT 0116 reported high rates of acute toxicity with 41%, 32%, and 1% of grade 3+, grade 4+, and grade 5+ toxicity, respectively.² Consequently, recent studies have explored 3-dimensional conformal radiation therapy (3D-CRT) planning and intensity modulated radiation therapy (IMRT) as potential methods to decrease acute and late treatment toxicity.⁴⁻⁷ As radiation treatment fields become increasingly conformal in an attempt to limit dose to normal critical structures, it becomes increasingly important to accurately identify treatment volumes on computed tomographic (CT)-based planning images, including the regional gastric lymph nodes (LN) stations. However, accurate identification of regional gastric LN stations may be difficult, particularly because postoperative gastric anatomy can vary substantially based on the type of surgical resection performed. To our knowledge, this is the first study to date that seeks to identify the radiographic location of gastric LN stations, particularly in the postoperative setting. This report serves as a template for the identification of the gastric LN stations to aid in definition of the elective clinical target volumes (CTV) for 3D-CRT and IMRT planning for gastric cancer.

Methods and materials

Four physicians, including 2 radiation oncologists, a diagnostic radiologist, and a surgical oncologist specialized in gastric cancer, convened over multiple meetings to develop this atlas. Four patients previously simulated for radiation treatment were selected to represent intact gastric anatomy and postoperative anatomy after 3 common surgical procedures employed for gastric cancer resection (Ivor-Lewis esophagogastrectomy, total gastrectomy with Roux-en-Y esophagojejunostomy, and subtotal gastrectomy with a Billroth II reconstruction). Once the cases were selected, CT-simulation images were retrieved from digital archive tapes for review. Each patient's CT datasets were copied to create a separate image set for this study. All CT simulation planning scans were performed with the patient in the supine position using oral and intravenous contrast with 2.5-mm slice thickness from 10-15 cm above the diaphragm to 2-3 cm below the iliac crest. Due to suboptimal timing of oral contrast delivery, gastric contrast is not appreciated on all scans. Surgical techniques and postoperative CT-simulation images were reviewed in detail by all 4 physicians. Gastric LN stations were identified slice by slice on CT simulation images by consensus and anatomic borders for each nodal station were identified radiographically.

Results

To better contextualize gastric LN stations, a review of relevant gastric anatomy, established gastric LN nomenclature, and gastric resection techniques is available online (Supplemental Appendix e1; available online only at www.practicalradonc.org).

Radiographic identification of gastric LN stations: Intact anatomy

Figure 1 depicts radiographic delineation of the gastric LN stations in slice-by-slice representative CT images of a patient taken with intact gastric anatomy. Moving in the cranial to caudal direction, the first perigastric LNs encountered are the left paracardial LNs (Fig 1A). The left paracardial LNs are anatomically defined medially by the gastric fundus, anterolaterally by the visceral peritoneum, posteriorly by the spleen, superiorly by the hemidiaphragm, and inferiorly by the gastric to the gastric body is devoid of any nodal tissue.

Moving inferiorly, the next LNs encountered are the greater curvature LNs, splenic hilum LNs, and right paracardial LNs (Fig 1B). Once the greater curvature is encountered, the nodal tissue on the left lateral perigastric

Figure 1 Intact gastric anatomy. (A) Left paracardial (orange); (B) greater curvature (blue), splenic hilum (brown), right paracardial (forest green); (C) greater curvature (blue), lesser curvature (dark blue), splenic (sky blue), splenic (sky blue), splenic (sky blue), splenic hilum (brown); (D) greater curvature (blue), lesser curvature (dark blue), splenic (sky blue), splenic hilum (brown), left gastric (aquamarine, dashed); (E) greater curvature (blue), lesser curvature (dark blue), splenic (sky blue), left gastric (aquamarine, dashed), paraortic (red), hepatoduodenal (bright green); (F) greater curvature (blue), lesser curvature (dark blue), splenic (sky blue), splenic (sky blue), paraortic (red), hepatoduodenal (bright green); common hepatic (dark purple), celiac (pink); (G) greater curvature (blue), lesser curvature (dark blue), splenic (red), paraortic (red), hepatoduodenal (bright green), suprapyloric (yellow); (H) greater curvature (blue), paraortic (red), pancreatic (lime green), superior mesenteric (violet), infrapyloric (green, dashed). See Fig 5 for color legend.



Figure 2 Ivor-Lewis esophagogastrectomy. (A) Greater curvature (blue), lesser curvature (dark blue), splenic hilum (brown), splenic (sky blue); (B) greater curvature (blue), lesser curvature (dark blue), splenic (sky blue), hepatoduodenal (spring green), suprapyloric (yellow), celiac (salmon pink), common hepatic (dark purple), left gastric (aquamarine, dashed), paraortic (red); (C) greater curvature (blue), splenic (sky blue), paraortic (red), infrapyloric (green, dashed); (D) greater curvature (blue), superior mesenteric (violet), pancreatic (lime green), paraortic (red); (E) pancreatic (lime green), paraortic (red). See Fig 5 for color legend.

region is termed the greater curvature LNs. The greater curvature LNs run along the short gastric vessels and both right and left gastroepiploic vessels, and they are bordered medially by the gastric body, anterolaterally by the ribs, and posteriorly by the spleen and splenic hilum LNs. Lying posterior to the greater curvature LNs, the splenic hilum LNs represent the nodal basin lying between the spleen and gastric body, bordered posterolaterally by the spleen, medially by the kidneys, extending inferiorly to cover all of the splenic hilum vasculature. In Fig 1B, the right paracardial LNs can also be identified, representing the narrow anatomic space that lies between gastric cardia

and liver, extending posteriorly to the aorta and inferiorly to drain into the lesser curvature LNs at the level of the gastric body.

Figure 1C depicts the lesser curvature and splenic artery LNs in relation to greater curvature and splenic hilum LNs. The lesser curvature LNs are defined superiorly by the right paracardial LNs, anteromedially by the liver, inferomedially by the suprapyloric LNs, laterally by the gastric body, and posteriorly by the kidney. The splenic artery LN basin surrounds the splenic artery. It is bordered anteriorly by the posterior aspect of the gastric body, posteriorly by the left kidney, laterally by the splenic hilum LNs, and medially by the celiac axis LNs. Figure 1D illustrates the location of the left gastric LNs in the context of other previously described LN stations. The left gastric LN station is defined as regional tissue surrounding the left gastric artery, starting inferiorly from its origin of the celiac axis to superiorly, running along the superior portion of the lesser curvature, where these LNs merge with the lesser curvature LNs. The left gastric LN station is bordered medially by the liver, superolaterally by the splenic artery LN basin, and inferolaterally by the celiac LNs.

Continuing inferiorly, Figure 1E illustrates the location of hepatoduodenal and paraortic LN stations. The hepatoduodenal LNs lie along the proper hepatic artery, common bile duct, and the portal vein, extending superiorly from the under surface of the liver to the superior portion of the duodenum inferiorly. The paraortic LNs are located within the region between and immediately adjacent to the aorta and inferior vena cava. Through consensus discussion, the superior border of the paraortic LNs was designated as 5-mm below the origin of the celiac axis. This LN basin extends inferiorly to the duodenal sweep, medially to the vertebral body, and laterally extending to 2-mm left of the aorta.

As named, the common hepatic LNs (Fig 1F) can best be identified by first identifying the common hepatic artery, which terminates to form the proper hepatic artery and gastroduodenal artery. This LN basin is bordered posteriorly by the paraortic LNs, posteromedial by the celiac LNs, anteriorly by the liver, anteroinferiorly by the suprapyloric LNs, and laterally by the hepatoduodenal LNs. Similarly, the celiac LNs are defined by the celiac artery, starting from its origin from the aorta to its termination where it branches and gives off the common hepatic artery, left gastric artery, and splenic artery.

Figure 1G illustrates the suprapyloric LNs, which lie directly superior to the gastric pylorus. The common hepatic LNs flow into the suprapyloric LNs, then flow leftward to join up with the lesser curvature LNs. The suprapyloric LNs are bordered anteriorly by the left lobe of the liver, posteriorly by the pancreatic body, and to the left by the inferior portion of the lesser curvature LNs. Lastly, the infrapyloric LNs, posterior pancreatic LNs, and the superior mesenteric LNs can be appreciated. The infrapyloric LNs lie immediately inferior to the gastric pylorus and anterior to the pancreatic head and superior mesenteric vessels. The posterior pancreatic LNs lie immediately posterior to the pancreatic head and anterior to the paraortic LNs. The superior mesenteric LNs reside anteriorly along the surface of the pancreatic head and neck, from the junction of the superior mesenteric artery and vein superiorly to the duodenal sweep inferiorly.

Considerations for LN identification in the postoperative setting

Although generally the radiographic definitions of gastric LN stations described above can be applied in the postoperative setting, due to the potential for differences in postsurgical anatomy it is important to discuss radiographic identification of gastric LN stations in the setting of the most common oncologic surgeries employed for resection of gastric cancers (Supplemental Appendix e2, Fig 1e, and Fig 2e; available online only at www. practicalradonc.org).

Ivor-Lewis esophagogastrectomy

Figure 2 represents the group consensus for gastric LN station identification in the postoperative setting after an Ivor-Lewis esophagogastrectomy. During this procedure all of the paracardial tissue is typically dissected, and thus it may be difficult to radiographically define paracardial LN stations after an Ivor-Lewis esophagogastrectomy. It is important to acknowledge, however, that depending on surgical technique, during an Ivor-Lewis esophagogastrectomy perigastric lymph nodes may be transposed into the thoracic cavity. Additionally, although the L and R paracardial and lesser curvature LN tissue may be completely dissected in the formation of a gastroesophageal anastomosis, there may still be nodal tissue here as evidenced by anastomotic recurrences which may occur. In our representative patient, above the staple line anastomosis there is no left paracardial, right paracardial, or lesser curvature nodal remnant tissue as all of these LNs have been completely dissected and the formation of a gastroesophageal anastomosis precludes any further identification of these nodal groups.

Moving inferiorly, at the transition of the gastric fundus and gastric body, the greater and lesser curvature LN basins can be identified, lying laterally and medially, respectively, to the stomach (Fig 2A). In an Ivor-Lewis esophagectomy, the splenic artery is not usually dissected and thus, identification of the splenic hilum and splenic LNs can be radiographically defined by the parameters discussed for intact anatomy. In contrast, the left gastric artery is ideally taken at its origin, although this is not a



Figure 3 Total gastrectomy with Roux-en-Y esophagojejunostomy. (A) Splenic hilum (brown), splenic (sky blue); (B) splenic hilum (brown), splenic (sky blue), hepatoduodenal (spring green), common hepatic (dark purple); suprapyloric (yellow); (C) splenic hilum (brown), paraortic (red), celiac (salmon pink), pancreatic (lime green), infrapyloric (green, dashed); (D) paraortic (red), pancreatic (lime green), superior mesenteric (violet). See Fig 5 for color legend.

universally adopted surgical approach. In the case of our patient, the left gastric artery was surgically removed, and thus the surgical clips demarcating the left gastric artery were contoured. Additionally, a Kocher maneuver may be performed such that the suprapyloric and infrapyloric nodes by be shifted medially and superiorly. A Kocher maneuver is a surgical maneuver in which the duodenum and head of the pancreas are mobilized from their retroperitoneal attachments. This allows the distal gastric remnant to more easily reach the mediastinum for anastamosis to the transected esophagus. All other gastric LN stations can be identified according to guidelines established for patients with intact gastric anatomy. Figure 2B-2E illustrates representative radiographic slices to further aid in identification of the suprapyloric, infrapyloric, hepatoduodenal, celiac, common hepatic, pancreatic, superior mesenteric, and paraortic LNs.

Total gastrectomy with Roux-en-Y esophagojejunostomy

During a total gastrectomy, the right and left gastric arteries are divided at their respective bases, and the entire

stomach is removed from the gastroesophageal junction to the duodenum just below the pylorus. Thus, the right and left paracardial and lesser and greater curvature LNs should ideally be completely dissected without residual nodal tissue. In contrast, the suprapyloric, infrapyloric, and left gastric LNs are variably dissected and therefore may be identifiable in postoperative imaging. Figure 3 depicts the group consensus for radiographic gastric LN station delineation in the postoperative setting after a total gastrectomy. Similar to a patient with intact gastric anatomy, identification of the splenic, splenic hilum, celiac, hepatoduodenal, common hepatic, pancreatic, superior mesenteric, and paraortic LN stations remains the same.

Subtotal gastrectomy

During a subtotal gastrectomy the left gastric artery is often dissected at its base, and thus surgical clips demarcating the left gastric artery were contoured to delineate this potential LN basin. However, in contrast to a total gastrectomy, because the proximal stomach is left intact in a subtotal gastrectomy, the right paracardial and left paracardial nodes and portions of the lesser curvature



Figure 4 Subtotal gastrectomy. (A) R paracardial (forest green), L paracardial (orange), splenic hilum (brown); (B) lesser curvature (dark blue), greater curvature (blue), splenic (sky blue), splenic hilum (brown); (C) greater curvature (blue), splenic (sky blue); paraortic (red), left gastric (aquamarine, dashed), celiac (salmon pink); (D) greater curvature (blue), splenic (sky blue); paraortic (red), left gastric (aquamarine, dashed), celiac (salmon pink); (D) greater curvature (blue), splenic (sky blue); paraortic (red), left gastric (aquamarine, dashed), celiac (salmon pink); common hepatic (dark purple); (E) hepatoduodenal (spring green), paraortic (red); (F) pancreatic (lime green), paraortic (red), superior mesenteric (violet). See Fig 5 for color legend.

and greater curvature LNs have not been surgically dissected. As a result, these LN basins can be readily identifiable on postoperative imaging. The infrapyloric and suprapyloric tissue are ideally removed during a subtotal gastrectomy, precluding any definitive identification of these LN stations after a subtotal gastrectomy. Figure 4 depicts the group consensus for radiographic gastric LN station delineation in the postoperative setting after a subtotal gastrectomy. Identification of the splenic, splenic hilum, celiac, hepatoduodenal, common hepatic, pancreatic, superior mesenteric, and paraortic LN stations remains similar to the intact anatomy.

LN Station Number	LN Location	Color	Color Swatch
1	Right Paracardial	Forest Green	
2	Left Paracardial	Orange	
3	Lesser Curvature	Dark Blue	
4	Greater Curvature	Blue	
5	Suprapyloric	Yellow	
6	Infrapyloric	Green	
7	Left Gastric	Aquamarine	
8	Common Hepatic	Dark Purple	
9	Celiac	Pink	
10	Splenic Hilum	Brown	
11	Splenic	Sky Blue	
12	Hepatoduodenal	Spring Green	
13	Posterior Pancreatic Head	Lime Green	
14	Superior Mesenteric	Violet	
15	Middle Colic	Not Depicted	Not Depicted
16	Paraortic	Red	

Figure 5 Regional lymph node stations of the stomach and Figs 1-4 color legend.

Discussion

We sought to establish a contouring atlas of the gastric LN stations to be used in defining clinical target volumes in 3D treatment planning for gastric cancers. As radiation treatment fields become increasingly conformal in an attempt to limit dose to normal critical structures, it becomes increasingly important to accurately identify treatment volumes on CT-based planning images, including the regional gastric LN stations. To our knowledge, this is the first study to date to attempt to establish anatomic guidelines for radiographic identification of gastric LN stations, particularly in the postoperative setting.

Two multimodality treatment strategies have emerged as viable options in the treatment of localized, resectable gastric cancer.^{2,8} In 2001, Intergroup 0116 established postoperative chemoradiation as an effective adjuvant therapy approach. With a median follow-up of 5 years, adjuvant chemoradiation improved overall survival (3year OS: 41% vs 50%, P < .001) compared with surgery alone.² However, despite these promising results, enthusiasm for adjuvant chemoradiation was dampened by high rates of acute toxicity (grade 3+: 41%, grade 4+: 32%), necessitating early treatment termination in more than onesixth of patients.² More recently, the Medical Research Council Adjuvant Gastric Infusional Chemotherapy (MAGIC) Trial has established perioperative chemotherapy with epirubicin, cisplatin, and 5-fluorouracil as a second potential treatment strategy, yielding a survival benefit at 5 years (23% vs 36%, P < .01).⁸ The MAGIC study does not address the role of radiation, and some have questioned whether the demonstrated benefit of chemotherapy may imply that adjuvant radiation may be omitted. To address this question, the Dutch Colorectal Cancer Group has recently launched the ChemoRadiotherapy after Induction Chemotherapy in Cancer of the Stomach (CRITICS) study, a multi-institutional, randomized controlled study, to investigate whether chemoradiation after preoperative chemotherapy and surgery leads to improved survival compared with perioperative chemotherapy and surgery without radiation. This study is currently underway and will hopefully further elucidate the role of adjuvant chemoradiation following preoperative chemotherapy. For now, determination of the optimal treatment strategy is generally decided on an individual basis or institutional preferences and is tailored to each patient's clinical presentation and histopathologic findings.

Based on studies evaluating the patterns of relapse after surgical resection,¹ general guidelines have been proposed to aid in definition of the clinical target volume for adjuvant radiation treatment fields based on location, T stage of the primary tumor, and N-stage.⁹ For nodepositive disease, wide coverage of the tumor bed, residual stomach, resection margins, and nodal drainage regions have been generally recommended.⁹ In the development of our atlas, there may initially appear to be a discrepancy in the general recommendation for coverage of perigastric LN stations that are frequently dissected during surgical resection and, therefore, not identified on our postoperative scans. However, by inclusion of the preoperative tumor bed and resection margin, more often than not the preoperative perigastric LN drainage basin is naturally included within the target volume. Therefore, this gastric LN contouring atlas is meant to supplement the previously established guidelines for definition of CTVs in the adjuvant treatment of gastric cancer.⁹

In an attempt to minimize acute and late toxicities, several recently published studies have explored the role of IMRT in the adjuvant treatment of gastric cancer. 5,10-12 Ringash et al⁵ found that, compared with 3D-CRT, IMRT was preferred in 89% of cases due to improved target coverage and sparing of the spinal cord, kidneys, liver, and heart. Minn et al¹¹ compared the clinical outcomes and toxicity among 57 patients with gastric or gastroesophageal adenocarcinoma treated with either 3D-CRT or IMRT. Although rates of acute grade 2+ gastrointestinal toxicity were similar, more patients required treatment breaks in the 3D-CRT group. Additionally, there was a significant increase in the 3D-CRT post-treatment serum creatinine from 0.8 mg/dL to 1.0 mg/dL (P = .02). Similar to other series,⁵ the authors in this study also reported decreased radiation doses to normal tissues, including the liver and kidneys.¹¹ Despite these promising results, other studies have suggested that IMRT may only confer a marginal benefit and should be considered in patients with risk factors for kidney disease or preexisting nephropathy.¹⁰ Future studies will further elucidate the potential benefit of IMRT in the adjuvant treatment of gastric cancer.

Our study had several limitations that should be addressed. First, the selected patients represent standard postoperative anatomy after 3 common surgical procedures; however, variations of surgical techniques may exist. Consequently, accurate radiographic identification of regional gastric LN stations may be difficult. Therefore, engaging in rigorous discussions with referring surgeons and radiologists is essential to determine each individual surgeon's preferred surgical techniques with respect to both the primary tumor resection and the gastric LN dissection. Additionally, all operative reports should be thoroughly reviewed in designing optimal postoperative treatment fields, and any remaining questions regarding the details of the surgical procedure should be addressed with the surgical oncologist. Importantly, variations in surgical technique can lead to wide variations in postoperative anatomy and that the patients seen postoperatively may have scans that are dissimilar relative to our figures. Variations in postoperative anatomy are likely to be most notable among patients undergoing subtotal gastrectomy or

Ivor-Lewis esophagogastrectomy, with respect to the gastric remnant. Additionally, due to limitations of this manuscript format, our study only presents representative slices of each patient's anatomy to highlight the locations of each of the LN stations.

Conclusions

These images should serve as a template for the definition of gastric LN stations to aid in the definition of elective CTVs to be used in treatment planning for gastric cancers. Future consensus studies should focus on establishing guidelines for definition of elective CTVs in the era of modern conformal therapy for the adjuvant treatment of gastric cancer.

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