Received:
7 August 2015

Revised:
24 November 2015

Accepted:
2 December 2015

doi: 10.1259/bjr.20150661

Cite this article as:

Kataria T, Gupta D, Basu T, Gupta S, Goyal S, Banerjee S, et al. Simple diagrammatic approach to delineate duodenum on a radiotherapy planning CT scan. *Br J Radiol* 2016; **89**: 20150661.

PICTORIAL REVIEW

Simple diagrammatic approach to delineate duodenum on a radiotherapy planning CT scan

¹TEJINDER KATARIA MD, DNB, ¹DEEPAK GUPTA MD, ¹TRINANJAN BASU MD, ²SHIVANI GUPTA MD, ¹SHIKHA GOYAL MD, DNB, ¹SUSOVAN BANERJEE MD, ¹ASHU ABHISHEK MD, ¹SHYAM S BISHT MD and ¹KUSHAL NARANG MD

¹Division of Radiation Oncology, Medanta The Medicity, Gurgaon, India

²Department of Radiology and Imaging, Medanta The Medicity, Gurgaon, India

Address correspondence to: Dr Trinanjan Basu

E-mail: trinanjan.doctor@gmail.com

ABSTRACT

In recent years, there has been increasing application of intensity-modulated radiotherapy and stereotactic body radiotherapy for the treatment of abdominal malignancies (stomach, pancreas, liver, spinal metastases). This warrants accurate delineation of organs at risk, especially the duodenum. The tortuous and curvy anatomy of duodenum often indistinguishable from adjoining organs is a practical challenge. Radiation Therapy Oncology Group (RTOG) has already published upper abdominal normal structure contouring guidelines to ease the delineation process. This pictorial essay following the RTOG guideline elaborates the step-by-step identification of the different parts of duodenum in relation to the adjoining important structures.

INTRODUCTION

The small bowel has three distinct portions namely duodenum, jejunum and ileum. All of these have large surface area and are important for nutrient absorption. In the management of pancreatico-hepatobiliary malignancies especially in the era of stereotactic body radiotherapy (SBRT), duodenum inadvertently became an important organ at risk (OAR). The importance primarily depends upon the location. Both acute (abdominal cramps, diarrhoea) and late (fibrosis, adhesion and obstruction) radiation toxicities have been very important for small bowel.^{1,2}

The essence of radiation oncology contouring relies upon accurate delineation. Keeping all these in mind, Radiation Therapy Oncology Group (RTOG) published upper abdominal normal structures contouring guidelines.³ Even with the existing guideline, the challenge in day-to-day practice is to delineate duodenum easily and accurately. We intend to propose a simple step-by-step pictorial essay of identifying all the four parts of the duodenum with RTOG guideline as the benchmark.

METHODS AND MATERIALS

For the ease of identification, we considered planning CT scans from patients planned for treatment of non-abdominal sites. Patients were asked to fast 4 h prior to CT scan. Only intravenous contrast was given with

2 ml kg⁻¹ of body weight with flow rate of 5 ml s⁻¹, and images were acquired in portal phase after a gap of 60 s from the time of injecting contrast. Planning scans were acquired in portal phase. The planning CT scans were obtained in free breathing with patient in the supine position and abdominal cast were applied.

Planning images were taken from the root of neck up till upper border of pelvis (L5–S1 junction) with 3-mm slice thickness in Siemens Biograph™ PET/CT scanner (Siemens Healthcare, Erlangen, Germany) with 64 slices. The planning images were transferred to Focal Sim planning software (Elekta, Crawley, UK) and preset abdominal window mode (Level 600; Width 40) was selected for contouring.

Before beginning the step-by-step contouring procedure, we would briefly outline the radiological anatomy of duodenum as follows:^{3,4}

first portion: begins after the pylorus, is retroperitoneal after the first approximate 5 cm

second (descending) portion: mostly vertical, encircling the head of pancreas and located to the right of the IVC (inferior vena cava) at vertebral levels L1 to L3

third (transverse) portion: mostly horizontal, crosses in front of the aorta and IVC and marks the end of the C-loop of the duodenum. On axial CT slices, third part is the last to appear.

Figure 1. Axial CT slices showing liver, stomach, spleen and aorta and inferior vena cava. Duodenum yet to begin.

Fourth (ascending) portion: travels superiorly and posteriorly to the left of superior mesenteric vessels and joins the jejunum. On axial CT slices, fourth part finishes even before the second or third part.

RESULTS

Following the RTOG upper abdominal contouring guideline, we would describe a method of contouring duodenum for easy reproducibility.

The following organs always need to be contoured in axial CT slices *viz.* stomach, spleen, bowel bag, liver, spinal cord, aorta, IVC, pancreas, both kidneys and lumbar vertebrae 1 to 3 (L1–L3), as these would guide in accurate delineation. Here, we would like to mention that for ease of reproducibility and after discussion with abdominal radiologist, we relied on mostly solid organs and great vessels for landmark. As for example RTOG defines inferior mesenteric vein as a transition between D4 and jejunum, we found little difficulty in identifying the same in planning CT images. For better delineation, oral contrast also needs to be used and we do not use oral contrast in radiotherapy planning CT scans as an institutional protocol.

The following colour codes were maintained while delineation:
liver: yellow
stomach: pink
spleen: light orange

Figure 2. Stomach has narrowed down into pylorus and lumbar vertebrae are yet to begin. The approximate next slice would begin as the duodenum's first part.

Figure 3. The first part like a bulb (duodenal cap) can be seen even when part of pyloric stomach continues. It is a part above lumbar (L1) vertebrae and always to the right.

kidney left and right: light and dark green, respectively

IVC: light green

aorta: brown

L1–L3: royal blue

pancreas: light blue

duodenum first part (D1): light pink; second part (D2): blue; third part (D3): green; and fourth part (D4): dark blue.

The following series of figures (Figures 1–15) describes different parts of duodenum in a craniocaudal fashion, mostly in axial CT slices and in the end coronal and sagittal views depicting all the four parts together.

One very important practical challenge we realized is between the start and the end of the duodenum. There is no standardized guideline to delineate duodenum when considered as a whole organ. We propose to start contouring from D2 as it is easily identifiable and then trace up and below for other parts. Eventually, the RTOG and our guideline will help in demarcating D1–D4. The contouring although should always be in axial section with help taken from coronal and sagittal view. As we are aware of duodenum motion and the critical issue of generating margin [so-called planning OAR volume (PRV)] in the days of

Figure 4. Approximate end of the duodenum first part (D1) where superiorly pylorus and towards left body of pancreas appears. The D1 takes a sharp vertical turn almost like a C-loop, and this is where the second part is about to begin. It is between the right and left lobes of liver, and both kidneys can be appreciated.

Figure 5. The duodenum second part continues and pancreatic head almost overlaps it on the left side, also inferior vena cava is seen in close proximity. Another landmark is both kidney's corticomedullary structures identified.

SBRT, the different parts and their movements need to be kept in mind. The same we are analyzing in a prospective dosimetric study by delineating different parts and documenting the motion of them separately.

DISCUSSION

Recent SBRT trials for upper abdominal cancers suggested that the toxicity profile remains similar to that of the standard fractionation. Review of the literature indicates that in SBRT treatment involving GI structures, standardization in contouring OARs is of significant value besides other considerations.⁵

Published data have also indicated that SBRT can be an alternative to surgery in patients with liver or abdominal lymph node oligometastases. The delivery of high dose per fraction with duodenum being in close vicinity warrants accurate delineation.⁶

For SBRT, the volume of small bowel receiving higher doses should also be minimized. The small bowel volume receiving >12.5 Gy in a single fraction should ideally be kept to <30 cm³ with avoidance of circumferential coverage above that dose; for

Figure 6. The duodenum first part (D1) is almost over and the duodenum second part (D2) continues. Important is liver lobes are about to end. Body of stomach, D1 and D2 are completely covering pancreatic head.

Figure 7. The duodenum second part seen as vertical roundish structure with pancreas on upper medial aspect.

a three- to five-fraction regimen, the maximum point dose should be <30.0 Gy.² There is a recent review which summarises the upper abdominal organs' tolerance to SBRT and pertaining quantitative analyses of normal tissue effects in the clinic (QUANTEC) data.⁵ While treating para-aortic lymph nodes with dose-escalated IMRT, limiting volume receiving 55 Gy (V_{55}) to below 15 cm³ may reduce the risk of duodenal complications.⁷ Similarly for treating unresectable pancreatic cancer with chemoradiation to a median dose of 50.4 Gy, duodenal V_{55} (Gy) >1 cm³ is an important dosimetric predictor of grade 2 or greater duodenal toxicity.^{8,9}

The American-French consensus recommendations also observed grade 2 toxicities of duodenum while irradiating locally advanced carcinoma pancreas.¹⁰

The duodenum and its different parts have variable mobility. The accuracy of SBRT warrants a safe PRV for duodenum. We are in the process of serially documenting motion of different parts of duodenum and then proposing a quantification of PRV. In this matter, the most important aspect of all the available literature emphasizes accurate delineation of the duodenum. An

Figure 8. The duodenum second part starts moving upward and medial turn and the duodenum fourth part (D4) can be seen. D4 remains very difficult to identify and standard guideline being inferior to the pancreatic body.

Figure 9. With aorta exactly in midline, liver almost disappearing, the duodenum second part (D2) and the duodenum fourth part (D4) are distinctively identified. D2 sandwiched between the right kidney and remaining parts of pancreas while D4 seen as a hollow structure superolateral to the aorta.

Figure 10. With the duodenum fourth part being a very small segment (around 2-2.5 cm, on a 3-mm CT cuts for sections), the further downward part would be the duodenum third part. It would be superolateral to the aorta.

Figure 11. The duodenum second part (D2) becomes more vertical while the duodenum third part (D3) remains in midline in close contact to the aorta. The fat plane almost disappears between D2 and D3. Further CT slices would have D3 alone.

Figure 12. The duodenum third part stays in front of both the inferior vena cava and aorta and occupies midline.

Figure 13. The duodenum third part almost towards the end but remains in midline only, anterior to the inferior vena cava and aorta.

Figure 14. (a, b) Coronal view of all four parts of the duodenum.

Figure 15. (a, b) Sagittal view of all four parts of the duodenum.

informal departmental survey identified the difficulty in duodenum contouring and often leads to overdrawing or underdrawing. This brief pictorial essay with simplified diagrams

specifically aimed at resolving all these issues. The motto is loud and clear: if you can't see it, you can't treat it and also you can't cure then.

REFERENCES

- Coia LR, Myerson RJ, Tepper JE. Late effects of radiation therapy on the gastrointestinal tract. *Int J Radiat Oncol Biol Phys* 1995; **31**: 1213–36.doi: [10.1016/0360-3016\(94\)00419-L](https://doi.org/10.1016/0360-3016(94)00419-L)
- Kavanagh BD, Pan CC, Dawson LA, Das SK, Li XA, Ten Haken RK, et al. Radiation dose volume effects in the stomach and small bowel. *Int J Radiat Oncol Biol Phys* 2010; **76**: S101–7.doi: [10.1016/j.ijrobp.2009.05.071](https://doi.org/10.1016/j.ijrobp.2009.05.071)
- Jabbour SK, Hashem SA, Bosch W, Kim TK, Finkelstein SE, Anderson BM, et al. Upper abdominal normal organ contouring guidelines and atlas: a Radiation Therapy Oncology Group consensus. *Pract Radiat Oncol*. 2014; **4**: 82–9.doi: [10.1016/j.prro.2013.06.004](https://doi.org/10.1016/j.prro.2013.06.004)
- RTOG upper abdominal normal organ contouring atlas: <http://www.rtog.org/CoreLab/ContouringAtlases/UpperAbdominalNormalOrganContouringConsensusGuidelines.aspx>
- Thomas TO, Hasan S, Small W Jr, Herman JM, Lock M, Kim EY, et al. The tolerance of gastrointestinal organs to stereotactic body radiation therapy: what do we know so far? *J Gastrointest Oncol* 2014; **5**: 236–46.doi: [10.3978/j.issn.2078-6891.2014.024](https://doi.org/10.3978/j.issn.2078-6891.2014.024)
- Almaghrabi MY, Supiot S, Paris F, Mahe MA, Rio E. Stereotactic body radiation therapy for abdominal oligometastases: a biological and clinical review. *Radiat Oncol* 2012; **7**: 126.doi: [10.1186/1748-717X-7-126](https://doi.org/10.1186/1748-717X-7-126)
- Verma J, Sulman EP, Jhingran A, Tucker SL, Rauch GM, Eifel PJ, et al. Dosimetric predictors of duodenal toxicity after intensity modulated radiation therapy for treatment of the para-aortic nodes in gynecologic cancer. *Int J Radiat Oncol Biol Phys* 2014; **88**: 357–62.doi: [10.1016/j.ijrobp.2013.09.053](https://doi.org/10.1016/j.ijrobp.2013.09.053)
- Kelly P, Das P, Pinnix CC, Beddar S, Briere T, Pham M, et al. Duodenal toxicity after fractionated chemoradiation for unresectable pancreatic cancer. *Int J Radiat Oncol Biol Phys* 2013; **85**: 143–9.doi: [10.1016/j.ijrobp.2012.09.035](https://doi.org/10.1016/j.ijrobp.2012.09.035)
- Tozzi A, Comito T, Alongi F, Navarra P, Iftode C, Mancosu P, et al. SBRT in unresectable advanced pancreatic cancer: preliminary results of a mono-institutional experience. *Radiat Oncol* 2013; **8**: 148.doi: [10.1186/1748-717X-8-148](https://doi.org/10.1186/1748-717X-8-148)
- Huguet F, Goodman KA, Azria D, Racadot S, Abrams RA. Radiotherapy technical considerations in the management of locally advanced pancreatic cancer: American-French consensus recommendations. *Int J Radiat Oncol Biol Phys* 2012; **83**: 1355–64.doi: [10.1016/j.ijrobp.2011.11.050](https://doi.org/10.1016/j.ijrobp.2011.11.050)