



# Changes in spleen volume after resection of hepatic colorectal metastases

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## ARTICLE INFORMATION

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**AIM:** To identify and describe changes in spleen volume occurring in patients with colorectal metastases to the liver after partial hepatectomy.

**MATERIALS AND METHODS:** Forty-one consecutive patients (20 men, 21 women) with histopathology-proven colorectal liver metastases who underwent partial hepatectomy between August 2007 and April 2011 were included. Liver and spleen volumes were measured by computed tomography (CT) volumetry on the most recent CT prior to surgery and on all CTs obtained within a year after partial hepatectomy. Patients were carefully evaluated for and excluded if they had co-morbid conditions known to cause splenomegaly or risk factors for portal hypertension such as underlying liver disease and portal vein thrombosis.

**RESULTS:** Thirty-two (78%) patients demonstrated an increase in spleen volume on the first post-operative CT, with more than a double increase in volume amongst five patients. Spleen volume increased by an average of 43% within 3 months of partial hepatectomy ( $p < 0.0001$ ) and remained increased through 6 months after surgery, returning to near baseline thereafter. In the remaining nine (22%) patients, the spleen was observed to decrease an average of 11% in volume on first postoperative CT ( $p < 0.005$ ).

**CONCLUSIONS:** Splenic enlargement after partial hepatectomy of colorectal metastases is a common finding on CT. Increased familiarity amongst radiologists of this phenomenon as likely reflecting physiological changes is important in order to avoid unnecessary evaluation for underlying conditions causing interval enlargement of the spleen.

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## Introduction

Liver regeneration following partial hepatectomy is a well-documented phenomenon.<sup>1</sup> In contrast, changes in spleen volume after partial hepatectomy have not been widely studied. Increase in spleen volume has been documented in healthy liver donors following graft resection, as

observed on postoperative computed tomography (CT) studies.<sup>1–5</sup> However, living adult donor transplants are infrequent and unlikely to be encountered by radiologists outside a large-volume centre.<sup>6,7</sup>

The aim of the present study was to describe changes in spleen volume amongst patients with partial hepatectomy for colorectal liver metastasis. Of the approximately 150,000 new colorectal cancer diagnoses in the United States each year, 35–55% will present with or develop liver metastases, and surgical therapy remains the treatment of choice for resectable lesions.<sup>8,9</sup> Following resection, patients frequently undergo CT for postoperative management and monitoring

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of metastatic disease. Therefore, it is important for radiologists to gain familiarity with postoperative changes affecting the spleen in this patient population.

## Materials and methods

### Patient selection

This study was approved by the institutional review board. Informed consent was waived due to the retrospective nature of the study. A record of all partial hepatectomies between August 2007 and April 2011 performed at Stanford Hospital was obtained through the surgical department. A review of patients' medical history found 93 patients with presumed colorectal adenocarcinoma liver metastasis as the surgical indication. Thirty-five patients were excluded from analysis due to lack of available preoperative CT images within a month prior to surgery or postoperative CT images within a year following surgery. An additional 14 patients were excluded for potential confounding causes of splenic enlargement including prior partial hepatectomy, known hepatitis or cirrhosis, postoperative sepsis/abscess, portal vein thrombosis, and treatment with oxaliplatin chemotherapy. The latter exclusion criterion was based upon reports that oxaliplatin can cause long-term sinusoidal injury with subsequent portal hypertension and splenic enlargement.<sup>10,11</sup> Other chemotherapeutics used to treat colorectal cancer have not been reported to affect spleen size. Three patients were also excluded for disease other than adenocarcinoma consistent with colorectal metastasis. Two patients with a history of alcohol abuse were included based on normal preoperative liver function tests, underlying normal liver tissue on histopathology, and lack of recent alcohol use. No patient had any pre-existing condition that was known to be associated with splenomegaly. The final subject group consisted of 41 patients, 21 women and 20 men, with a mean age of  $61.2 \pm 12.7$  ( $\pm$  SD) years at the time of surgery.

### Study design

Liver and spleen volumes were measured on baseline and postoperative CT. All baseline CT examinations were performed within a month before hepatectomy. For patients with multiple imaging evaluations prior to surgery, the most recent CT examination was used as baseline. All postoperative CT examinations were performed within a year following hepatectomy, accounting for a total of 259 available CT examinations. Postoperative CT images were not included in the final analysis if they were performed after initiation of oxaliplatin chemotherapy, liver radiation therapy, development of portal vein thrombosis, or interventional procedures such as portal vein embolization—all of which may affect spleen volume and therefore potentially confound the results. Many patients had metastatic recurrence after resection and were placed on oxaliplatin, accounting for the majority of excluded CT examinations. There were a total of 89 postoperative CT examinations in the final analysis.

CT examinations were performed on a 16 or 64-detector CT machine (Siemens Sensation 64, Erlangen, Germany and LightSpeed VCT, GE Medical Systems, Milwaukee, WI, USA). Studies were performed at various contrast-enhanced phases (arterial and portal venous with slight variation in delay) unless contrast medium administration was contraindicated. All spleens were evaluated for focal lesions to rule out the rare event of underlying splenic disease.

### CT volumetry

Liver and spleen volumes were measured by CT volumetry using a GE Advantage Windows Workstation (GE Healthcare, Milwaukee, WI, USA). Surface areas were manually traced on every 10 mm axial section, with slices in-between extrapolated by the computer program. All axial tracings, including those extrapolated by the computer, were confirmed and corrected as necessary before measuring organ volume. Volume was calculated as the area of tracing in each section multiplied by section thickness. Volumes of major vessels such as inferior vena cava/main hepatic portal vein and major fissures were excluded in measurements. All volumetric measurements were obtained by a single observer (K.E.J.) to eliminate interobserver variability.

### Statistical analysis

Statistical calculations were performed using Matlab 2008 Statistical Toolbox (Mathworks, Natick, MA, USA). Mann–Whitney U-tests were used for comparison of increased versus decreased spleen volume groups. Wilcoxon signed-rank tests evaluated differences between paired measurements of preoperative and postoperative organ volume measurements. A two-tailed *p*-value of less than 0.05 was considered significant.

## Results

Liver and spleen volumes were measured on baseline and postoperative CT examinations within a year of partial hepatectomy amongst 41 patients with liver metastases of primary colorectal adenocarcinoma origin. At baseline, the average liver and spleen volumes for all patients were  $1545 \pm 50$  cm<sup>3</sup> ( $\pm$  standard error of the mean) and  $280 \pm 24$  cm<sup>3</sup>, respectively. For all 41 patients combined, spleen volume increased an average of 26% on first postoperative CT compared to baseline ( $p < 0.0001$ ). However, not all patients demonstrated postoperative splenic enlargement and the degree of volume change was variable. Most notably, 10 patients had a greater than 50% increase in spleen volume, of whom five had spleens that more than doubled in volume.

Based on comparison of spleen volume measurements at baseline and first postoperative CT examinations, two groups of patients were identified: (1) those with an increase in spleen volume and (2) those with a decrease in spleen volume after surgery (Table 1). Thirty-two (78%) of the 41 patients had postoperative splenic enlargement (Figs 1 and 2), with spleen volume increasing  $37 \pm 8\%$  on

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