

Technique and outcomes of robot-assisted median arcuate ligament release for celiac artery compression syndrome

Stijn J. J. Thoolen, BS,^a Walderik J. van der Vliet, BS,^a Tara S. Kent, MD,^a Mark P. Callery, MD,^a Martin J. Dib, MD,^a Allen Hamdan, MD,^b Marc L. Schermerhorn, MD,^b and A. James Moser, MD,^a
Boston, Mass

Objective: Celiac artery compression by the median arcuate ligament (MAL) is a potential cause of postprandial abdominal pain and weight loss that overlaps with other common syndromes. Robotic technology may alter the current paradigm for surgical intervention. Open MAL release is often performed with concurrent bypass for celiac stenosis due to the morbidity of reintervention, whereas the laparoscopic approach is associated with high rates of conversion to open due to bleeding. We hypothesized that a robot-assisted technique might minimize conversion events to open, decrease perioperative morbidity, and defer consideration of vascular bypass at the initial operative setting.

Methods: We retrospectively analyzed patients treated for MAL syndrome by a multidisciplinary team at a tertiary medical center between September 2012 and December 2013. Diagnosis was based on symptom profile and peak systolic velocity (PSV) >200 cm/s during celiac artery duplex ultrasound imaging. All patients underwent robot-assisted MAL release with simultaneous circumferential neurolysis of the celiac plexus. Postoperative celiac duplex and symptom profiles were reassessed longitudinally to monitor outcomes.

Results: Nine patients (67% women) were evaluated for postprandial pain (100%) and weight loss (100%). All patients had celiac stenosis by mesenteric duplex ultrasound imaging (median PSV, 342; range, 238–637 cm/s), and cross-sectional imaging indicated a fishhook deformity in five (56%). Robot-assisted MAL release was completed successfully in all nine patients (100%) using a standardized surgical technique. Estimated blood loss was <50 mL, with a median hospital stay of 2 days (range, 2–3 days). No postoperative complications of grade ≥ 3 , readmissions or reoperations were observed. All patients (100%) improved symptomatically at the 25-week median follow-up. Three patients experienced complete resolution on postoperative celiac duplex ultrasound imaging, and six patients showed an improved but persistent stenosis (PSV >200 cm/s) compared with preoperative velocities ($P < .05$ by Wilcoxon signed rank). No patients required additional treatment.

Conclusions: Robot-assisted MAL release can be performed safely and effectively with avoidance of conversion events and minimal morbidity. Potential factors contributing to success are patient selection by a multidisciplinary team and replication of the open surgical technique by means of robot-assisted dexterity and visualization. The need for delayed reintervention for persistently symptomatic celiac stenosis is uncertain. (*J Vasc Surg* 2015;61:1278–84.)

Median arcuate ligament (MAL) syndrome (MALS), also known as celiac artery compression syndrome, is a rare condition first described by Harjola in 1963.¹ The symptom profile attributed to MALS typically occurs in

young women² who present with postprandial epigastric pain (80%), weight loss (48%), nausea (9.7%), and diarrhea (7.5%).³ The etiology of MALS remains controversial⁴ but has been attributed to visceral ischemia and neurogenic causes. Variability in the presenting symptoms and the unpredictable response to surgical treatment, combined with the morbidity of the open surgical approach, has led to skepticism about its clinical significance.^{5,6} Furthermore, unrecognized MALS might become clinically significant during pancreatoduodenectomy in up to 4% patients after division of the gastroduodenal artery and require intraoperative management for hemodynamic compromise in the celiac distribution.⁷

The MAL is a fibrous band of the diaphragmatic crus surrounding the origin of the celiac artery. Low insertion of the ligament or high takeoff of the celiac axis, or both, can cause extrinsic compression of the celiac artery.⁸ Compression of the celiac artery by the MAL was identified in 34% of individuals from the overall population in an autopsy study.⁹

Surgical division of the MAL is the most widely accepted treatment during open MAL release, although concurrent celiac bypass or patch angioplasty is often

From the Institute for Hepatobiliary and Pancreatic Surgery^a and the Division of Vascular and Endovascular Surgery,^b Beth Israel Deaconess Medical Center, Harvard Medical School.

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Reprint requests: A. James Moser, MD, Institute for Hepatobiliary and Pancreatic Surgery, Beth Israel Deaconess Medical Center, Stoneman 9, 330 Brookline Ave, Boston, MA 02215 (e-mail: ajmoser@bidmc.harvard.edu).

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performed simultaneously due to the morbidity of reintervention for residual stenosis.³ A minimally invasive approach may alter the risk-to-benefit ratio of simultaneous celiac bypass and permit a stepwise approach to treating celiac stenosis with less overall morbidity. A laparoscopic approach has been described with favorable morbidity and faster recovery compared with open but suffers from a high risk of conversion (9.1%) for serious technical causes such as arterial bleeding (7.4%) and pneumothorax (2.5%).^{3,10} The robot-assisted minimally invasive approach combines high-definition three-dimensional visualization with superior manual dexterity and precision to permit circumferential dissection around the celiac plexus and control of bleeding, potentially creating superior surgical outcomes with fewer emergent conversion events.

METHODS

Study population and design

The Institutional Review Board at Beth Israel Deaconess Medical Center (BIDMC) approved this retrospective study of robot-assisted MAL release between September 2012 and December 2013. Patient consent was not required for this retrospective case review. Exclusion criteria included ostial stenosis or atherosclerosis of the celiac trunk, celiac artery aneurysm, prior revascularization, including celiac bypass grafts or endovascular stents, and Ehlers-Danlos syndrome.

All patients with suspected MALS were referred by their primary care physician or a gastroenterologist to the BIDMC Division of Gastroenterology for further assessment. Diagnostic evaluation for all patients excluded more common pathologies by means of upper and lower endoscopy, gallbladder ultrasound imaging, blood and breath testing for *Helicobacter pylori*, and celiac disease, as indicated, in addition to gastric emptying studies. Patients with suspected MALS then underwent computed tomography (CT) or magnetic resonance (MR) angiography and were evaluated by a multidisciplinary team of vascular (M.S., A.H.) and pancreatic surgeons (A.J.M., T.S.K., M.P.C.) according to the BIDMC clinical pathway for celiac artery compression syndrome.

Celiac duplex imaging was required before and after surgery. Although some patients undergo psychologic testing before their referral, the BIDMC clinical pathway does not require a psychologic evaluation or cessation of narcotics among patients with typical symptoms and duplex studies consistent with MALS.

Nine patients underwent robot-assisted (DaVinci Si, Intuitive Surgical, Sunnyvale, Calif) release of the MAL during the study period, and their medical records were reviewed to evaluate short-term postoperative morbidity and treatment efficacy. Patient characteristics included age, gender, body mass index (BMI), American Society of Anesthesiologists Physical Status Classification score, Charlson Comorbidity Index,¹¹ and history of abdominal surgery. Postprandial abdominal pain, history of weight loss, fear of eating, nausea, vomiting, diarrhea, and bloating were recorded before and after surgery.

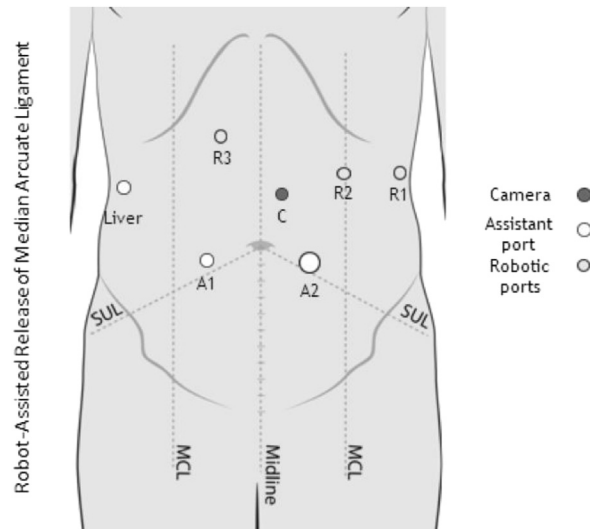


Fig 1. Placement of robot and assistant ports for release of median arcuate ligament (MAL). A, Assistant port; MCL, midclavicular line; R, robot port; SUL, superior iliac spine-umbilical line.

Clinical success was defined as complete resolution of abdominal symptoms after surgery. Clinical failure included no change in symptoms and patients reporting improved but persistent and less severe symptoms. Morbidity and readmission were monitored for 90 days. Findings on diagnostic imaging (CT or MR angiography, conventional arteriography, and mesenteric duplex ultrasound imaging) were collected. Peak systolic velocity (PSV) >200 cm/s in the celiac artery on mesenteric duplex imaging indicated celiac stenosis >70%.¹² Provocative maneuvers with inspiration and expiration were performed during all mesenteric duplex ultrasound procedures.

Statistical analysis

Distribution characteristics for each outcome variable were checked for normalcy. None of the outcome variables were distributed normally and are therefore displayed as median and range. Statistical significance of changes in PSV on mesenteric duplex imaging where assessed using the Wilcoxon signed rank test. Values of $P < .05$ were considered significant.

Operative technique

Patients are placed supine on a split-leg operating table, with the left arm tucked. The chest is taped to the table, and the feet are supported by padded footrests. The steps of the operative technique are shown the [Video](#) (online only).

Step 1: Trocar placement. Robotic (8 mm) and laparoscopic (5 mm) trocars are inserted according to [Fig 1](#), with the exception of a 12-mm assistant trocar (A2) in the right or left abdomen depending on body habitus. The liver retractor port is located in the right anterior axillary line to expose the origin of the left gastric artery. The assistant ports permit caudal and posterior retraction of the

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