



# A nationwide analysis of median arcuate ligament release between 2010 and 2020: a NSQIP Study

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## Abstract

**Background** Median arcuate ligament syndrome is a rare disease with overlapping symptoms of broad foregut pathology. Appropriately selected patients can benefit from a laparoscopic or open median arcuate ligament release. Institutional series have reported the outcomes of open and laparoscopic techniques but there are no nationwide analysis comparing both techniques and overall trends in treatment.

**Methods** Cross-sectional study using the American College of Surgeons-National Surgical Quality Improvement Project from 2010 to 2020. Celiac artery compression syndrome cases were identified by International Classification of Diseases (ICD) codes and categorized as open or laparoscopic. Trends in the use of each technique and 30-day complications were compared between the groups.

**Results** A total of 578 open cases (76%) and 185 laparoscopic cases (24%) were identified. There was an increase adoption of the laparoscopic approach, with 22% of the cases employing this technique at the end of the study period, compared to 7% at the beginning of the study period. The open group had a higher prevalence of hypertension (26% vs 18%,  $p=0.04$ ) and bleeding disorders (5% vs 2%,  $p=0.03$ ). Laparoscopic approach had a shorter length of stay (2.3 days vs 5.2 days,  $p<0.0001$ ), lower major complication rates (0.5% vs 4.0%,  $p=0.02$ ) and lower reoperation rates (0% vs 2.6%,  $p=0.03$ ). Overall mortality was 0.1%.

**Conclusion** Overall numbers of surgical intervention for treatment of median arcuate ligament increased during this time-frame, as well as increased utilization of the laparoscopic approach. It appears to be an overall safe procedure, offering lower rates of complications and shorter length of stay.

**Keywords** Celiac artery compression · Median arcuate ligament syndrome · Surgical release of median arcuate ligament · Laparoscopy · NSQIP

Median arcuate ligament syndrome (MALS) is defined as a symptomatic extrinsic compression of the celiac axis caused by the median arcuate ligament (MAL) [1]. Often considered a rare entity, more recently a study using the Nationwide

Inpatient Sample showed an increasing number of patients with this diagnosis [2]. There remains controversy regarding this diagnosis and its epidemiology, as celiac axis compression by the MAL can be found incidentally in up to 7.3% of patients who received cross-sectional abdominal imaging for other reasons [1, 3].

MALS remains a diagnostic challenge as patients typically present with non-specific symptoms such as post-prandial abdominal pain and weight loss, overlapping with other common foregut pathologies [4]. The disease predominantly affects female patients with a lower body mass index in whom psychiatric comorbidities are frequently present [5]. Although there is no group consensus agreement for the diagnosis of MALS, several authors have proposed diagnostic criteria [1, 3, 6–8]. These criteria are

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aimed at aiding the diagnosis of MALS, in which patients have a negative gastrointestinal workup and evidence of celiac axis compression on imaging, most commonly dynamic duplex ultrasound measuring flow velocities and computed tomography and angiographic reconstruction.

Operative treatment with MAL release, first described in the 1960's by Harjola and Dunbar, has remained the standard treatment [9, 10]. This procedure can be done open, laparoscopic or more recently robotic-assisted. However, there is not enough evidence to help guide surgeons as to which operative approach is superior over the other, with limited data coming from single-institution series [4, 7, 8, 11–16]. In the largest study to our knowledge, no difference was found in postoperative outcomes between the laparoscopic and open approach [6]. Nevertheless, this study was founded on a literature review including 20 papers in a 49 year period. The objective of this study was to examine the trends in MAL release in the United States in the past 10 years, providing a comprehensive data analysis to ascertain if there is a difference in perioperative outcomes between operative approaches.

## Materials and methods

### Study design

This was a cross-sectional study using the American College of Surgeons-National Surgical Quality Improvement Project (ACS-NSQIP) database from 2010 to 2020. This is a nationwide registry that has been validated for surgical outcomes research and contains multiple variables, including preoperative, intraoperative, and 30-day postoperative data. The information is collected using a systematic sampling process by trained surgical clinical reviewers. The study was deemed exempt of review by the Institutional Review Board.

### Population

As there is no specific current procedural terminology (CPT) code for MAL release, data were filtered using the international classification of diseases (ICD) 9 and 10 codes [17]. All patients with the diagnosis of “celiac artery compression syndrome” based on ICD-9 code 447.4 or ICD-10 code I77.4 captured in the ACS-NSQIP database were included. The database does not include patients under 18 years and therefore they were not included in this study. It is important to note that the sampling process does not allow the inclusion of more than three procedures during an 8-day period.

## Definitions and primary outcome

Cases were individually classified as either “open” or “laparoscopic” based on their CPT codes listed. To evaluate the trends in MAL release, we calculated the total cases count, and the proportions for each approach. The rate of 30-day postoperative complications as stipulated on the ACS-NSQIP Chapter 4 manual was also assessed [18].

Complications were further grouped in seven different categories. Wound complications included wound dehiscence, superficial, deep, and organ space surgical site infections. Pulmonary complications included pneumonia, unplanned intubation, pulmonary embolism, deep vein thrombosis and failure to wean. Renal complications included progressive renal insufficiency and acute kidney injury. Cardiovascular complication included stroke, cardiac arrest and myocardial infarction. Infectious complications included urinary tract infection, sepsis, septic shock and *Clostridium Difficile*.

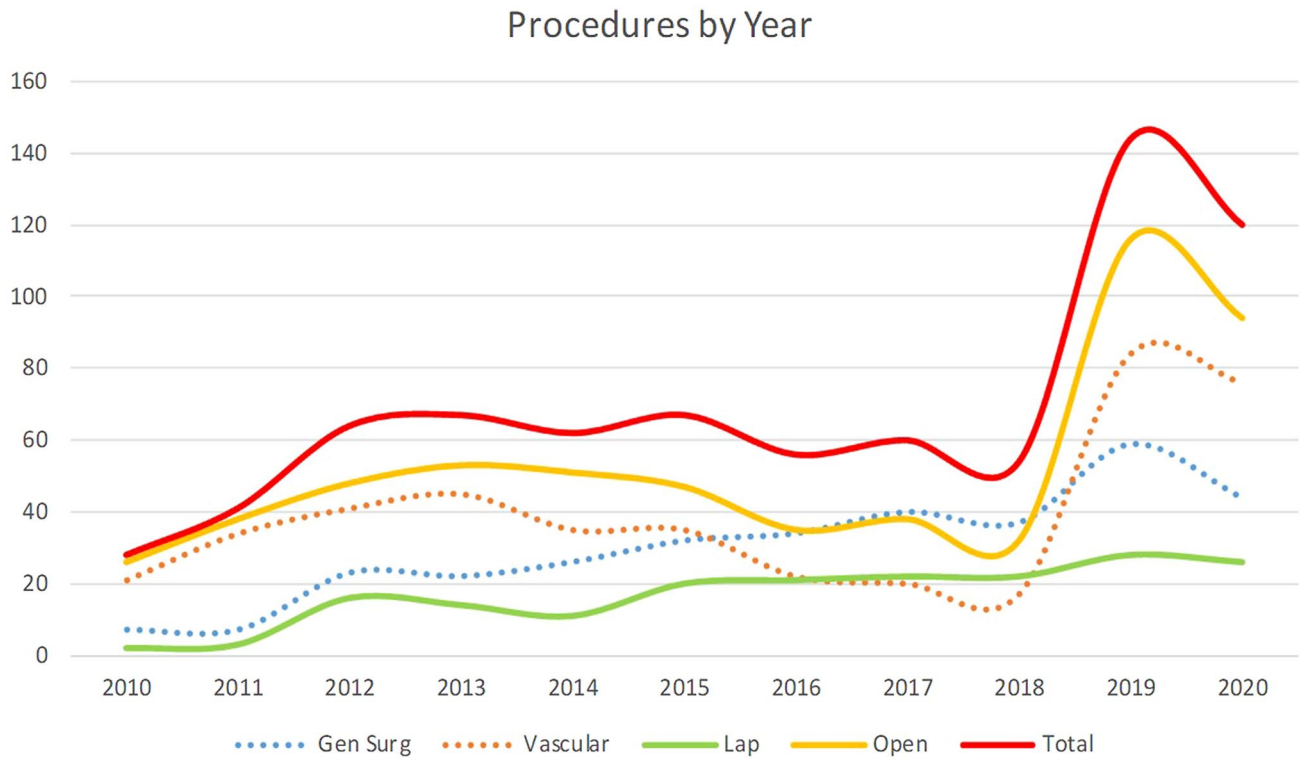
A major complication was assumed on Clavien-Dindo groups III to V, which included organ space surgical site infection, reintubation, failure to wean, progressive renal insufficiency, stroke, cardiac arrest, myocardial infarction, septic shock, return to the operating room and death [19]. All other complications were classified as minor complications.

### Statistical analysis

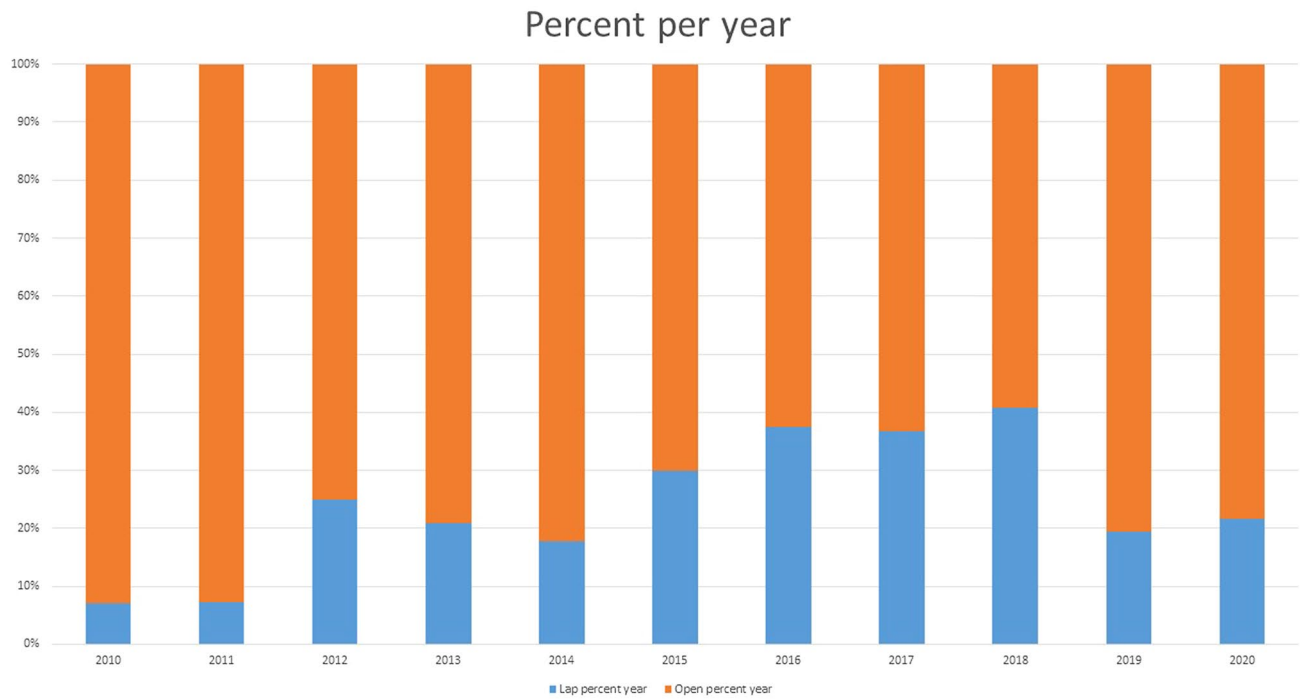
All statistical analyses were performed with SAS version 9.4 (SAS, Cary, NC, USA). Preoperative, intraoperative and postoperative variables were compared between groups using the *T*-test and Chi-squared test for continuous and categorical variables, respectively. The Fischer exact test was used for categorical variables when an observed value was <5. Statistical significance was considered at  $P < 0.05$ . Unless otherwise indicated, results are reported as total and percentages for categorical variables, means and standard deviations for continuous variables.

## Results

A total of 763 patients were identified during the study period, of which 578 were classified as open (76%) and 185 as laparoscopic (24%). The number of cases done every year increased from 28 in 2010 to a maximum of 144 in 2019 (Fig. 1). There was an increased use of the laparoscopic approach during the study period as well. In the first 2 years only 7% of the cases were done laparoscopically, with an increase up to a maximum of 41% of the cases employing this technique in 2018 (Fig. 2). In a similar way, the number



**Fig. 1** Total procedures done by year, operative approach and service



**Fig. 2** Percent of cases using each approach by year

of cases performed by general surgery increased over the study period, overpassing the number of cases done by vascular surgery in 2016 (Fig. 1).

The baseline characteristics of the entire cohort and each group are shown in Table 1. The majority of patients were female (74%), white (87%) and non-Hispanic (96%) with a mean age of 44 years old. The average body mass index was 24 kg/m<sup>2</sup>. Most patients were classified as American Association of Anesthesia (ASA) 1 and 2 (61%) and had a low prevalence of comorbidities, of which hypertension was most common (24%). The only differences between groups was seen in hypertension (open 26% vs laparoscopic 18%,

$p=0.04$ ) and bleeding disorders (open 5% vs laparoscopic 2%,  $p=0.03$ ).

The CPT codes for laparoscopic procedures included: 49329 unlisted laparoscopic procedure of the abdomen, peritoneum and omentum (68%), 44180 laparoscopic enterolysis separate procedure (22%) and 43659 unlisted laparoscopic procedure stomach (5%). Those for open procedures included: 49010 exploration, retroperitoneal area with or without biopsy (25%), 37799 unlisted procedure vascular surgery (17%), 39599 unlisted procedure diaphragm (13%), 35761 exploration, with or without lysis of artery (13%), 35631 aortoceliac bypass other than vein (9%) and 49000

**Table 1** Baseline characteristics

	Total <i>n</i> = 763 <i>n</i> (%)	Laparoscopic <i>n</i> = 185	Open <i>n</i> = 578	<i>p</i>
Gender				
Female	567 (74)	132 (71)	435 (75)	0.29
Male	196 (26)	53 (29)	143 (25)	
Race				
Asian	5 (0.6)	1 (0.5)	4 (0.7)	0.52
Black	30 (4)	4 (2)	26 (4)	
Unknown	60 (8)	16 (8)	44 (8)	
White	668 (87)	164 (89)	504 (87)	
Ethnicity				
Hispanic	24 (3)	8 (4)	16 (3)	0.29
Non-Hispanic	739 (96)	177 (96)	562 (97)	
ASA				
Class 1&2	466 (61)	121 (65)	345 (60)	0.18
Class 3&4	295 (39)	64 (35)	231 (40)	
Hypertension	182 (24)	34 (18)	148 (26)	<b>0.04</b>
Smoker	147 (19)	27 (15)	120 (21)	0.06
Weight Loss	107 (14)	28 (15)	79 (14)	0.62
Dyspnea	54 (7)	15 (8)	39 (7)	0.53
COPD	36 (5)	5 (3)	31 (5)	0.14
Diabetes	37 (5)	9 (5)	28 (5)	0.99
Bleeding disorder	34 (5)	3 (2)	31 (5)	<b>0.03</b>
Steroid	31 (4)	8 (4)	23 (4)	0.84
Cancer	4 (0.5)	0 (0)	4 (0.7)	0.58
Dependent	4 (0.5)	1 (0.5)	3 (0.5)	0.99
Congestive heart failure	2 (0.2)	1 (0.5)	1 (0.2)	0.43
Dialysis	1 (0.1)	0 (0)	1 (0.2)	0.99
Ascites	1 (0.1)	0 (0)	1 (0.2)	0.99
Renal failure	0 (0)	0 (0)	0 (0)	0.99
mean ± SD				
Age	44 ± 18	43 ± 17	44 ± 19	0.40
BMI	24 ± 5	24 ± 5	24 ± 5	0.90

Bold value indicates statistically significant

ASA American Society of Anesthesiologist, COPD chronic obstructive pulmonary disease, SD standard deviation, BMI body mass index

exploratory laparotomy, celiotomy with or without biopsy (6%).

Operative characteristics are depicted in Table 2. Vascular surgery was the index service in 430 of all cases (56.3%). A laparoscopic approach for MAL release was utilized in 98% of the cases by general surgeons while non-general surgeons utilized this approach far less frequently, in 2% of cases ( $p < 0.0001$ ). The mean operative time was similar between groups (140 vs 144 min,  $p = 0.56$ ). A transfusion was given in 7.3% and 1.1% of the open and the laparoscopic cases, respectively ( $p = 0.0008$ ). The mean length of stay was shorter for the laparoscopic group (2.3 days vs 5.2 days,  $p < 0.0001$ ).

The overall complication rate for MAL release was 12.1%. Major complications occurred in 3.1% of the entire cohort. The open group had a higher rate of major complications (4.0% vs 0.5%,  $p = 0.02$ ), pulmonary complications (2.6% vs 0%,  $p = 0.03$ ) and reoperations (2.6% vs 0%,  $p = 0.03$ ). Other complications were more commonly encountered in the open group but there was no statistically significant difference (Table 3). Only 1 mortality occurred in the open group (0.2%).

## Discussion

MALS is a debilitating disease in which diagnosis is made by first eliminating other common foregut etiologies of symptoms and confirmation by radiographic studies [1]. As with other rare entities, most of the data on this disease come from single institutional series. Although its pathophysiology is still matter of debate, surgical treatment has been the standard of care since it was first described in the 1960's [5, 9, 10]. In adequately selected cases, postoperative symptom relief occurs in up to 96% of the cases [6]. We found that

in the decade of 2010–2020, there has been an increasing volume of MAL release as well as an increased utilization of the laparoscopic approach. In addition, when comparing the laparoscopic and open approach, we found data supporting minimally invasive surgery given its lower complication rate and length of stay.

Although the true incidence of the disease is unknown, Rezig et al. reported 33,951 cases of MALS were diagnosed in a 12 year period using the Nationwide Inpatient Sample [2]. Interestingly, in their study only 2.4% of all cases identified had undergone surgery. In our study, the number of patients operated steadily increased over the years with a concomitant adoption of the laparoscopic approach. This could be a reflection of a better understanding of the disease process and its treatment, with current studies suggesting a neurogenic cause rather than vascular ischemia [5, 20]. As Goodall et al. accurately pointed out, MALS exists and increase awareness of the disease is warranted [3]. Additionally, the adoption of laparoscopic approaches and resultant lower peri-operative complications may make referring physicians and surgeons more likely to offer surgical intervention as a treatment.

The first description of a laparoscopic MAL release was in 2000 by Roayaie et al. [21]. After their original report, other groups reported their experience in small single-institution case series [4, 8, 11, 12]. A main concern of the laparoscopic approach is uncontrolled bleeding, reported in 9.1% of cases, necessitating a rapid conversion to a laparotomy [6]. Although our study was not able to directly assess the conversion rate, only 1 case had concomitant CPT codes 49000 and 49320, which could be translated to a 0.5% conversion rate, though this likely underestimates the true occurrence rate. The conversion rate previously published by our group was 10.3% in a study from 2007 to 2014, however, in a later study from 2018 to 2019 no conversions occurred

**Table 2** Operative characteristics

	Total <i>n</i> = 763	Laparoscopic <i>n</i> = 185	Open <i>n</i> = 578	<i>p</i>
	Mean ± SD			
Operative time	143 ± 69	140 ± 66	144 ± 70	0.56
Length of stay	4.5 ± 4.7	2.3 ± 3.2	5.2 ± 4.9	<b>&lt; 0.001</b>
	n (%)			
Service				
General surgery	331 (43.4)	182 (98)	149 (25.8)	<b>&lt; 0.001</b>
Thoracic surgery	2 (0.3)	0 (0)	2 (0.3)	
Vascular surgery	430 (56.3)	3 (2)	427 (73.8)	
Transfusion	44 (5.8)	2 (1.1)	42 (7.3)	<b>&lt; 0.001</b>

Bold values indicate statistically significant

SD standard deviation

**Table 3** Complications

	Total <i>n</i> = 763 <i>n</i> (%)	Laparoscopic <i>n</i> = 185	Open <i>n</i> = 578	<i>p</i>
Any complication	92 (12.1)	17 (9.2)	75 (13.0)	0.17
Major complication	24 (3.1)	1 (0.5)	23 (4.0)	<b>0.02</b>
Minor complication	68 (8.9)	16 (8.7)	52 (9.0)	0.78
Mortality	1 (0.1)	0 (0)	1 (0.2)	0.99
Wound complication	15 (2.0)	2 (1.1)	13 (2.2)	0.54
Superficial SSI	9 (1.2)	2 (1.1)	7 (1.2)	0.99
Deep SSI	1 (0.1)	0 (0)	1 (0.2)	0.99
Organ/space SSI	4 (0.5)	0 (0)	4 (0.7)	0.58
Dehiscence	2 (0.3)	0 (0)	2 (0.3)	0.99
Pulmonary complication	15 (2.0)	0 (0)	15 (2.6)	<b>0.03</b>
Pneumonia	10 (1.3)	0 (0)	10 (1.7)	0.13
Unplanned reintubation	5 (0.6)	0 (0)	5 (0.9)	0.34
Pulmonary embolism	1 (0.1)	0 (0)	1 (0.2)	0.99
Deep vein thrombosis	1 (0.1)	0 (0)	1 (0.2)	0.99
Failure to wean	5 (0.6)	0 (0)	5 (0.9)	0.34
Renal complication	3 (0.4)	1 (0.5)	2 (0.3)	0.57
Progressive renal insufficiency	3 (0.4)	1 (0.5)	2 (0.3)	0.57
Acute kidney injury	0 (0)	0 (0)	0 (0)	0.99
Cardiovascular complication	3 (0.4)	0 (0)	3 (0.5)	0.99
Stroke	0 (0)	0 (0)	0 (0)	0.99
Cardiac arrest	1 (0.1)	0 (0)	1 (0.2)	0.99
Myocardial infarction	2 (0.3)	0 (0)	2 (0.3)	0.99
Infectious complication	15 (2.0)	2 (1.1)	13 (2.2)	0.54
Urinary tract infection	11 (1.4)	1 (0.5)	10 (1.7)	0.48
Sepsis	3 (0.4)	1 (0.5)	2 (0.3)	0.57
Septic shock	0 (0)	0 (0)	0 (0)	0.99
<i>Clostridium difficile</i>	2 (0.3)	0 (0)	2 (0.3)	0.99
Other complications				
Reoperation	15 (2.0)	0 (0)	15 (2.6)	<b>0.03</b>
Readmission	57 (7.5)	15 (8.1)	42 (7.3)	0.70

Bold values indicate statistically significant

SSI surgical site infection

in 50 cases done with minimally invasive techniques [5, 7]. In this regard, it is our institutional practice for MAL release to be performed by a trained minimally invasive surgeon with assistance from a vascular surgeon if needed.

It is important to point out that in the current study laparoscopic cases were more commonly performed by general surgeons and at the same time, the number of procedures performed by general surgeons increased over the study period. These findings could partially explain the increased adoption of the laparoscopic approach, in addition to the growing evidence published during the same time demonstrating that laparoscopic MAL release is safe [4–7]. In a similar way, this growing evidence in combination to data demonstrating symptomatic improvement can also explain the rising number of cases done over time peaking in 2019.

Interestingly, the absolute number dropped in 2020 which we attribute to the overall decrease in surgical volume seen due to the COVID-19 pandemic [22].

Prior advocates of the laparoscopic approach had claimed a theoretical shorter length of stay but no actual comparison had been made up to this point [4, 21]. Our study demonstrates that patients treated laparoscopically leave the hospital on average 3 days sooner. In addition, laparoscopic MAL release demonstrated a lower complication rate. However, it is important to point out that regardless of the approach, MAL release appears to be a safe procedure with a low major complication rate, and it should be considered in appropriately selected patients with MALS.

Since the first robotic MALR was published in 2007, several studies have shown the safety and feasibility of



this approach [7, 13, 14, 23]. Unfortunately, in our study we were unable to identify robotic cases, and there is even a possibility that some of those classified as laparoscopic had actually been robotic. In that regard, Shin et al. demonstrated that both the laparoscopic and robotic-assisted techniques were similar with the only disadvantage of a more proficient assistant needed for laparoscopic cases [7]. Additional concerns about robotic surgical intervention include the loss of haptic feedback, which may make sensation between the celiac artery, aorta, and overlying nervous and muscular fibers less clear.

Our study has some limitations inherent to the nature of retrospective studies that need to be noted. The lack of a common CPT code for MAL release might have decrease the number of actual cases done during the study period making our results prone to selection bias. Even though each case was individually classified as open or laparoscopic this could be prone to misclassification bias as well. Conversions to open from laparoscopy are likely under-reported. Also, as our data only includes 30-day outcomes, it is impossible to establish if there was symptomatic improvement. However, to our knowledge, this is the first study to compare the national trends and outcomes of open and laparoscopic MAL release using the ACS-NSQIP database. Given the low incidence of the disease and the difficulty that carrying out a randomized control trial would entail, we hope our results will guide patients and surgeons to make informed decisions in the management of MALS.

Increased surgical treatment of MALS was detected in the past decade in the United States. The adoption of a laparoscopic approach has seen an increase use as well and it appears to be superior to the open approach in terms of length of stay, blood loss, and complications rate.

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**Author contributions** Study concept and design: GRV, WMP, MK. Acquisition, analysis and interpretation: GRV, JSBG. Drafting the manuscript: All authors. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: GRV. Administrative, technical or material support: JPP, RC, JR, SN. Study supervision: WMP, MK.

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## Declarations

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Ricard Corcelles, Salvador Navarrete, Woosup M. Park have no conflicts of interest or financial ties to disclose.

## References

1. Terlouw LG, Moelker A, Abrahamsen J et al (2020) European guidelines on chronic mesenteric ischaemia—joint United European Gastroenterology, European Association for Gastroenterology, ENDOSCOPY AND NUTRITION, European Society of Gastrointestinal and Abdominal Radiology, Netherlands Association of Hepatogastroenterologists, Hellenic Society of Gastroenterology, Cardiovascular and Interventional Radiological Society of Europe, and Dutch Mesenteric Ischemia Study group clinical guidelines on the diagnosis and treatment of patients with chronic mesenteric ischaemia. *United Eur Gastroenterol j* 8(4):371–395. <https://doi.org/10.1177/2050640620916681>
2. Rezig AB, Desai SS, Afifi RO et al (2015) Celiac artery decompression for median arcuate ligament syndrome: a United States national inpatient sample study. *J Vasc Surg* 61(2):585–586. <https://doi.org/10.1016/j.jvs.2014.11.040>
3. Goodall R, Langridge B, Onida S, Ellis M, Lane T, Davies AH (2020) Median arcuate ligament syndrome. *J Vasc Surg* 71(6):2170–2176. <https://doi.org/10.1016/j.jvs.2019.11.012>
4. El-Hayek KM, Titus J, Bui A, Mastracci T, Kroh M (2013) Laparoscopic median arcuate ligament release: are we improving symptoms? *J Am Coll Surg* 216(2):272–279. <https://doi.org/10.1016/j.jamcollsurg.2012.10.004>
5. Weber JM, Boules M, Fong K et al (2016) Median arcuate ligament syndrome is not a vascular disease. *Ann Vasc Surg* 30:22–27. <https://doi.org/10.1016/j.avsg.2015.07.013>
6. Jimenez JC, Harlander-Locke M, Dutson EP (2012) Open and laparoscopic treatment of median arcuate ligament syndrome. *J Vasc Surg* 56(3):869–873. <https://doi.org/10.1016/j.jvs.2012.04.057>
7. Shin TH, Rosinski B, Strong A et al (2021) Robotic versus laparoscopic median arcuate ligament (MAL) release: a retrospective comparative study. *Surg Endosc* 36(7):5416–5423. <https://doi.org/10.1007/s00464-021-08877-1>
8. Diab J, Diab V, Berney CR (2022) A diagnostic workup and laparoscopic approach for median arcuate ligament syndrome. *ANZ J Surg*. <https://doi.org/10.1111/ans.17514>
9. Dunbar JD, Molnar W, Beman FF, Marable SA (1965) Compression of the celiac trunk and abdominal angina: preliminary report of 15 cases. *Am J Roentgenol* 95(3):731–744. <https://doi.org/10.2214/ajr.95.3.731>
10. Harjola PT, Lahtiharju A (1968) Celiac axis syndrome. *Am J Surg* 115(6):864–869. [https://doi.org/10.1016/0002-9610\(68\)90537-0](https://doi.org/10.1016/0002-9610(68)90537-0)
11. Pather K, Kärkkäinen JM, Tenorio ER et al (2021) Long-term symptom improvement and health-related quality of life after operative management of median arcuate ligament syndrome. *J Vasc Surg* 73(6):2050–2058.e4. <https://doi.org/10.1016/j.jvs.2020.10.074>
12. van Petersen AS, Vriens BH, Huisman AB, Kolkman JJ, Geelkerken RH (2009) Retroperitoneal endoscopic release in the management of celiac artery compression syndrome. *J Vasc Surg* 50(1):140–147. <https://doi.org/10.1016/j.jvs.2008.12.077>
13. Roberts B, Pevsner R, Alkhoury F (2020) Robotic approach for median arcuate ligament release in pediatrics. *J Laparoendosc Adv Surg Tech* 30(1):92–96. <https://doi.org/10.1089/lap.2019.0337>

14. Fernstrum C, Pryor M, Wright GP, Wolf AM (2020) Robotic surgery for median arcuate ligament syndrome. *JSL* 24(2):e2020.00014. <https://doi.org/10.4293/JSL.2020.00014>
15. Coelho JCU, Hosni AVE, Claus CM et al (2020) Treatment of median arcuate ligament syndrome: outcome of laparoscopic approach. *ABCD, arq bras cir dig* 33(1):e1495. <https://doi.org/10.1590/0102-672020190001e1495>
16. Sultan SA, Acharya Y, Mustafa M, Hynes N (2021) Two decades of experience with chronic mesenteric ischaemia and median arcuate ligament syndrome in a tertiary referral centre: a parallel longitudinal comparative study. *Cureus*. <https://doi.org/10.7759/cureus.20726>
17. Roddy SP (2010) Laparoscopic versus open celiac ganglionectomy in patients with median arcuate ligament syndrome. *J Vasc Surg* 52(5):1419. <https://doi.org/10.1016/j.jvs.2010.09.030>
18. American College of Surgeons (2013) Chapter 4 ACS-NSQIP variables & definitions. ACS NSQIP operations manual. American College of Surgeons, Chicago
19. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 240(2):205–213. <https://doi.org/10.1097/01.sla.0000133083.54934.ae>
20. Barbon DA, Hsu R, Noga J, Lazzara B, Miller T, Stainken BF (2021) Clinical response to celiac plexus block confirms the neurogenic etiology of median arcuate ligament syndrome. *J Vasc Interv Radiol* 32(7):1081–1087. <https://doi.org/10.1016/j.jvir.2021.04.003>
21. Roayaie S, Jossart G, Gitlitz D, Lamparello P, Hollier L, Gagner M (2000) Laparoscopic release of celiac artery compression syndrome facilitated by laparoscopic ultrasound scanning to confirm restoration of flow. *J Vasc Surg* 32(4):814–817. <https://doi.org/10.1067/mva.2000.107574>
22. Mattingly AS, Rose L, Eddington HS et al (2021) Trends in US surgical procedures and health care system response to policies curtailing elective surgical operations during the COVID-19 pandemic. *JAMA Netw Open* 4(12):e2138038. <https://doi.org/10.1001/jamanetworkopen.2021.38038>
23. Jaik NP, Stawicki SP, Weger NS, Lukaszczyk JJ (2007) Celiac artery compression syndrome: successful utilization of robotic-assisted laparoscopic approach. *J Gastrointest Liver Dis* 16(1):93–96

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