

ORIGINAL RESEARCH

Robot Assisted Laparoscopy for Median Arcuate Ligament Syndrome Relief

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Objective: To evaluate the outcomes of robot assisted laparoscopic surgery for median arcuate ligament syndrome (MALS) relief.

Methods: This was a single centre and retrospective study, including all consecutive patients with symptomatic MALS treated with robot assisted laparoscopic surgery. Symptom relief and quality of life (QoL) were evaluated post-operatively. A comparison between the peak systolic velocity (PSV) of the coeliac artery (CA) measured pre-operatively and post-operatively was carried out.

Results: Nine interventions were performed. No conversion to laparotomy was required. There was post-operative abdominal pain relief in eight patients and QoL was improved in seven patients. Post-operatively, the CA PSV decreased (175 (IQR 160 - 195) cm/s vs. 365 (IQR 350 - 419) cm/s; $p < .001$).

Conclusion: MALS relief with robot assisted laparoscopy is safe and provides satisfactory outcomes in terms of symptom relief and CA compression release.

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INTRODUCTION

Median arcuate ligament syndrome (MALS) is an anatomico-clinical entity in which the coeliac artery (CA) is compressed by an interweaving of fibres developed between the two diaphragmatic pillars. This is a rare condition, present in about two in 100 000 patients;¹ it is more common in women than in men,² and mainly affects young patients aged 30–50 years,³ causing post-prandial abdominal pain, most commonly epigastric. The high prevalence of asymptomatic patients with radiological signs of CA compression is the main reason for misdiagnosis.^{4,5} Owing to a debated pathophysiology, there are currently no clear recommendations for surgical management for this rare vascular condition, even though it is accepted that surgical release of the CA is indicated only in symptomatic patients presenting with CA compression confirmed by vascular exploration examination in the absence of an alternative diagnosis. In addition to the open surgical option requiring a laparotomy and consisting of the division of the anomalous fibrous diaphragmatic bands overlying the CA,⁶ laparoscopic techniques with promising results were reported in the early 2000s,^{7–9} either with conventional laparoscopy or robot assisted laparoscopy

to perform the procedure. The present study aimed to evaluate the clinical and duplex ultrasound (DUS) results of robot assisted laparoscopic surgical release in patients with MALS, and to assess the quality of life (QoL) of these patients following surgical management.

MATERIALS AND METHODS

Inclusion criteria

All consecutive patients presenting with MALS, managed with robot assisted laparoscopic surgery, were included. The diagnosis of MALS was based on clinical, DUS, and computed tomography angiography (CTA) criteria: typical abdominal pain, CA stenosis greater than 70% on CTA with DUS peak systolic velocity (PSV) greater than 200 cm/s^{10,11} with the patient fasting, in inspiration and expiration, and after elimination of any other alternative diagnoses by a gastroenterological assessment, including at least a consultation and a gastroscopy.

Surgical technique

The steps of this procedure are shown in Supplementary Video S1. With the patient in a reverse Trendelenburg tilting position of 40°, arms alongside the body and legs apart, under general anaesthesia, with a nasogastric tube on suction, a pneumoperitoneum is induced by the inflation of carbon dioxide to 14 mmHg (Fig. 1A), by an open laparoscopy technique of the umbilicus or the right iliac fossa (McBurney point), with the placement of an 8 mm AirSeal Access Port (reference iAS8-100LP; CONMED, Utica, NY, USA) connected to an AirSeal iFS (reference AS-iFS 1; CONMED).

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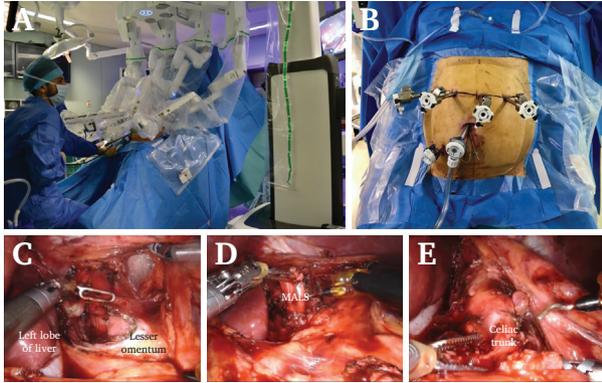


Figure 1. (A) Patient installation. (B) Trocars placement. (C) Lesser omentum opening. (D) Median arcuate ligament section. (E) Released coeliac trunk.

Four additional 8 mm trocars (da Vinci Xi 8mm Bladeless Optical Obturator [reference 470359]; Intuitive, Sunnyvale, CA, USA) are then placed on a supra-umbilical arcuate transverse line midway between the xyphoid process and the umbilicus, under laparoscopic control. Another 5 mm trocar can be added in the right iliac fossa, allowing the assistant to improve exposure using a liver retractor (Fig. 1B). The da Vinci Xi robot is then docked from the patient's left side. The required instruments for the procedure are a permanent cautery hook (reference 470183; Intuitive), a fenestrated bipolar forceps (reference 471205; Intuitive), monopolar curved scissors (reference 470179; Intuitive), a large needle driver (reference 471006; Intuitive), a suction irrigator (reference 480299; Intuitive), and a laparoscopic liver retractor. After exploring the abdominal cavity with the 8 mm endoscope plus, 0° (reference 470056; Intuitive), the falciform ligament of liver is transected and the pars flaccida of the lesser omentum opened (Fig. 1C), allowing the mobilisation of the left lobe of liver upwards and to the right with the fourth arm of the robot. The oesophagus is mobilised to the left, allowing better exposure of the aortocoeliac region. The diaphragmatic pillars are then dissected and division of the left diaphragmatic pillar is made approximately 3 cm below the oesophageal hiatus. The anterior surface of the coeliac aorta is approached by antegrade dissection, step by step, allowing identification of the lymphadenomatous and fibrous tissue, sheathing the CA, with the coeliac nerve plexus, constituting the MAL. The MAL is then sectioned vertically with the cautery hook (Fig. 1D), making it possible to free the origin of the left gastric artery, as well as the origin and the first few centimetres of the CA, until its bifurcation (Fig. 1E). After control of haemostasis, the pars flaccida is closed by a continuous overlock. Insufflation is stopped, pneumoperitoneum exsufflated and the trocars removed.

Supplementary video to this article can be found online at <https://doi.org/10.1016/j.ejvsf.2022.06.002>.

The following is the supplementary data to this article:- Video S1 Robot assisted laparoscopy for median arcuate ligament syndrome.

Peri-operative data

Operating times were collected intra-operatively for the following steps: (1) time of skin incision; (2) start and end time of robot docking; (3) start and end time of the lesser omentum opening and exposure of the MAL; (4) start and end time of the MAL dissection; and end time of the surgical procedure, corresponding to the time of dressings.

The time of the surgical approach was defined as the duration between the onset of the lesser omentum opening and the end of exposure of the MAL. The total duration of surgical intervention corresponded to the time elapsed between the skin incision and the time of dressings. Blood loss and need for conversion were also noted.

Post-operative data

Length of hospitalisation, need for re-intervention, and DUS PVS of the CA were recorded.

Quality of life

QoL assessment was carried out by sending the French adaptation of the 'Gastrointestinal Quality of Life Index' (GIQLI) questionnaire^{12,13} by post to all patients post-operatively, with a telephone reminder in the event of no response 15 days after posting. For this questionnaire, which investigates the status of patients with gastrointestinal disease with 36 questions, a score of ≥ 126 indicates good QoL (healthy volunteers); a score of ≤ 96 is associated with poor QoL. The maximum possible score is 144.¹³

Outcomes

The main outcomes were relief of digestive symptoms post-operatively and change in CA PSV measured by DUS pre- and post-operatively. The secondary endpoint was QoL evaluation post-operatively.

Statistical analysis

The results are presented as median (interquartile range (IQR)) for continuous variables. A p value $< .05$ was considered to be statistically significant. Comparison of the CA PSV pre- and post-operatively measured by DUS was done with the Wilcoxon signed rank test after the pairing of samples. Statistical analysis was done with STATA (Stata/BE 17.0 for Mac; StataCorp, College Station, TX, USA).

RESULTS

Demographic parameters

Nine patients underwent robotic release of the CA (six women and three men). The median age of the patients was 45 (IQR 28 - 61) years and the median body mass index was 19.92 (IQR 18.50 - 29.39) kg/m². The American Society of Anesthesiologists classification was 1 in four patients, 2 in two patients, and 3 in three patients.

The first patient to undergo a robotic release of the CA was operated on in 2017. Since then, the average number of patients included per year was 1.8 ± 0.45 , with a

Table 1. Pre-operative clinical presentations of nine patients with median arcuate ligament syndrome.

Patient	Age – y	Sex	BMI – kg/m ²	Pre-operative symptoms	Duration of symptoms – mo
1	54	Female	29.7	Abdominal pain	10
2	69	Female	18	Abdominal pain	24
3	28	Male	18.83	Abdominal pain, weight loss, vomiting	48
4	61	Male	31	Abdominal pain	15
5	32	Male	17.53	Abdominal pain, weight loss	20
6	45	Female	19.92	Abdominal pain, weight loss	6
7	72	Female	25.4	Abdominal pain, vomiting	4
8	18	Female	18.5	Abdominal pain	24
9	20	Female	29.39	Abdominal pain	6

BMI = body mass index.

maximum of two patients per year. From 2007 to 2021, three patients underwent a conventional open CA release and were excluded. No patient underwent conventional laparoscopic CA release without robotic assistance.

Descriptive analysis

Clinical presentation. The pre-operative clinical presentations of the patients are provided in Table 1. Symptoms (mostly abdominal pain) were present for 15 (IQR 6 - 24) months before the start of the investigations.

Surgical management. All interventions were performed by the same surgeon (F.T.). No patient required open conversion. Median intra-operative blood loss was 27.78 (IQR 0 - 50) mL.

The median duration of robot use was 57 (IQR 46 - 68) minutes. The median time for robot docking was 8 (IQR 7 - 10) minutes, the median duration of surgical approach was 22 (IQR 12 - 37) minutes, and the median time taken to divide the MAL was 24 (IQR 22 - 26) minutes. The median total duration of the intervention was 115 (IQR 97 - 137; Table 2) minutes.

Post-operative outcomes. The median post-operative hospital stay was 3 (IQR 2 - 3) days.

One immediate post-operative complication occurred: acute ischaemia of both lower limbs following thrombosis of a prosthetic aortobifemoral bypass, which required immediate thrombo-embolectomy of the bypass by direct approach to both common femoral arteries.

One patient was re-admitted for abdominal pain and vomiting eight days post-operatively. CTA and DUS did not

find any haemorrhagic complications or residual stenosis of the CA. The symptoms resolved quickly with symptomatic treatment, including painkillers and anti-emetics.

One patient underwent CA angioplasty and stenting four months after the first intervention, due to the persistence of the initial symptomatology with persistent significant stenosis of the CA seen on a follow up CTA. The median duration of follow up was 22.67 (IQR 10.03 - 44.23) months. No patient died during the follow up period (Table 3).

Primary outcome results

Five patients had relief of any symptoms after surgery and four patients had persistent post-operative symptoms. Four patients described post-operative weight gain, with a median weight increase of 3.00 (IQR 2 - 3) kg for these patients.

Post-operative CA PSV was lower in all patients (175 (IQR 160 - 195) cm/s vs. 365 (IQR 350 - 419) cm/s; $p < .001$) (Table 3).

Secondary outcome results

All patients answered the GIQLI questionnaire 22.13 (IQR 10.00 - 43.83) months post-operatively: six spontaneously within 15 days of sending the letter and three after a telephone reminder. The median GIQLI score post-operatively was 115 (IQR 104 - 129). Three patients had a score >126, indicating a good QoL and four had an intermediate score (between 96 and 126). Two patients had a score <96, corresponding to a poor QoL.

Table 2. Surgical management of nine patients with median arcuate ligament syndromes.

Patient	Duration of docking – min	Duration of surgical approach – min	Duration of ligament section – min	Total duration of intervention – min
1	7	38	23	95
2	12	12	16	97
3	8	11	26	94
4	5	3	63	115
5	4	37	24	107
6	8	18	20	140
7	10	38	31	195
8	7	22	25	137
9	13	22	22	116

Table 3. Post-operative outcomes in nine patients with median arcuate ligament syndrome.

Patient	Post-operative symptoms	Pre-operative PSV — cm/s	Post-operative PSV — cm/s	Duration of follow up — mo
1	None	380	198*	28.10
2	Decreased abdominal pain	350	212	22.67
3	Vomiting, gastro-oesophageal reflux	420	170	10.27
4	Dyspepsia, gastro-oesophageal reflux	365	175	10.03
5	None	320	193	2.37
6	None	419	100	44.43
7	Post-prandial diarrhoea	455	160	50.90
8	None	299	147	44.23
9	None	360	195	0.73

PSV = peak systolic velocity.

* = after complementary stenting of the CA.

DISCUSSION

This study highlights that robot assisted laparoscopic CA release for MALS is safe and offers satisfactory midterm results, based on DUS criteria and QoL questionnaires.

Regarding symptom relief, the results are in agreement with those reported previously, with 47.1% of patients describing complete resolution of symptoms, 26.5% partial resolution, and 14.7% the persistence of symptoms.¹⁴

The present results showed that this technique allows effective CA release with a significant post-operative reduction of CA PSV; despite this, symptoms could persist, meaning that ischaemia was probably not the only source of symptoms for some patients.

QoL was investigated using the GIQLI score. Only a few studies that sought to assess QoL after surgical management of MALS were found in the literature. This score has been described as a valuable measure to characterise extensively the symptoms and effect on QoL, validated in various gastrointestinal diseases; however, the results in the setting of CA release are disparate. In a study that included 81 patients with CA release performed with open surgery and 19 patients with laparoscopic CA release, mean GIQLI score was 102 ± 26 with an estimated five year freedom from symptoms of $67\% \pm 7\%$.¹⁵ Another publication describing laparoscopic CA release in six patients reported a GIQLI score of 129 ± 6 .¹⁶ Similar results for management with robotic assistance were not found in the present study.

Surgical positioning is crucial to performing the procedure; the patient should be positioned safely. Aortobifemoral graft thrombosis with straps around the thighs was used at the beginning of the present experience to prevent patients from slipping due to the reverse Trendelenburg tilting position, which probably caused an extrinsic intra-operative compression at the level of the superficial femoral arteries below the distal anastomoses, causing bypass thrombosis.

Theoretically, laparoscopic treatment vs. open surgery has several advantages, including lower morbidity, less post-operative pain, faster recovery, fewer post-operative

intra-abdominal adhesions, less blood loss, faster return to professional activities, and a better aesthetic result in terms of scar size.³ The first CA release by conventional laparoscopic surgery was conducted in 2000 by Roayaie et al.,¹⁷ and the first with robotic assistance in 2007 by Jaik et al.¹⁸

Laparoscopy allows surgeons to release the CA without laparotomy, sectioning the ligament with the coeliac plexus and fibrous and lymphatic tissue. However, adequate and sufficient laparoscopic experience is required, with a potentially long learning curve, in particular in vascular surgery where use of the robot is not frequent. The robot assisted laparoscopic approach has the potential to increase the surgeons learning curve,¹⁹ but the methods used to measure and define learning curves remain imprecise and sometimes inconsistent.²⁰ Robotic assistance provides improved surgical precision due to the instrument's seven degree of freedom joints, tremor filtration, and three dimensional vision of abdominal cavity structures.²¹ In addition, the robotic procedure gives the surgeon better comfort during the procedure than in open or conventional laparoscopic surgery, allowing work with more stability and safety in a narrowed space. However, robot assisted procedures are more expensive than equivalent procedures in open or conventional laparoscopic surgery,²² but the surgical comfort and safety of the patient is paramount. Furthermore, the robot requires the use of 8 mm trocars, whereas five mm trocars would be sufficient for a conventional laparoscopic approach, which might lead to more post-operative pain.

This study has several limitations. Owing to its retrospective nature, there was no assessment of pre-operative QoL, which is a major limitation. Indeed, it would be interesting to assess the improvement in the GIQLI score post-operatively. Furthermore, the QIGLI score was not completed for all patients at the same time post-operatively. Finally, although the largest series of patients having benefited from robot assisted laparoscopic surgery for MALS to date is presented, the series is small, with only nine cases, mainly because of the rarity of this condition.

CONCLUSION

CA release with robot assisted laparoscopy in the setting of MALS is safe and provides satisfactory outcomes in terms of symptom relief and CA compression release.

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CONFLICTS OF INTEREST

None.

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