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Efficacy and durability of robotic heller myotomy for achalasia: patient symptoms and satisfaction at long-term follow-up

Kyle A. Perry · Aliyah Kanji · Joseph M. Drosdeck · John G. Linn · Anthony Chan · Peter Muscarella · W. Scott Melvin

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Abstract
Background Laparoscopic Heller myotomy (LHM) has become the standard treatment for achalasia in the USA. Robot-assisted Heller myotomy (RHM) has emerged as an alternative approach due to improved visualization and fine motor control, but long-term follow-up studies have not been reported. We sought to report the long-term outcomes of RHM and compare them to those of LHM.
Methods A retrospective cohort study was performed for patients who underwent laparoscopic or RHM between 1995 and 2006. Long-term follow-up was performed via mail or telephone questionnaire. The primary outcome measure was durable relief of dysphagia without need for further intervention. Secondary outcomes included gastroesophageal reflux symptoms, disease-specific quality of life, and patient satisfaction with their operation.
Results Seventy-five patients underwent laparoscopic ($n = 19$) or robotic ($n = 56$) myotomy during the study period. Long-term follow-up was obtained in 53 (71 %) patients with a median interval of 9 years. RHM was associated with a decreased mucosal injury rate (0 vs. 16 %, $p = 0.01$) and median hospital stay (1 vs. 2 days, $p < 0.01$) compared to conventional laparoscopy. All patients reported initial dysphagia relief, and 80 % required no further intervention. This did not differ between groups. Sixty-two percent required medications to control reflux symptoms at long-term follow-up, including 56 % following robotic myotomy and 80 % after laparoscopic myotomy ($p = 0.27$). Overall, 95 % of patients were satisfied with their operation, and 91 % would choose surgery again given the benefit of hindsight.
Conclusion There is a dearth of long-term follow-up data to support the effectiveness of RHM. This study demonstrates durable dysphagia relief in the vast majority of patients with a high degree of patient satisfaction and a low rate of esophageal mucosal injury. While a significant proportion of patients report reflux symptoms, these symptoms are well controlled with medical acid suppression.

Keywords Achalasia · Heller myotomy · Robotic Heller myotomy · Robotics · Laparoscopy

Since its inception in the early 1990s, laparoscopic Heller myotomy (LHM) with partial fundoplication has emerged as the treatment of choice for achalasia in many centers due to effective and durable relief of dysphagia, low morbidity, and positive impact on patient disease-specific quality of life [1–6]. This procedure is associated with significant dysphagia relief in greater than 90 % of patients with relatively low operative morbidity, but may produce acid reflux requiring medical acid suppression in a subset of patients [7–12]. Durability of dysphagia relief has been demonstrated in small series with follow-up intervals up to 10 years, but relatively few long-term follow-up studies have been completed [13–17].

First reported in 2001, robot-assisted Heller myotomy (RHM) has emerged as an alternative approach [18]. Advocates of this approach have cited improved visualization and fine motor control, which allow creation of a

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K. A. Perry (✉) · A. Kanji · J. M. Drosdeck · J. G. Linn · A. Chan · P. Muscarella · W. S. Melvin
Center for Minimally Invasive Surgery, The Ohio State University Wexner Medical Center, 410 W. 10th Avenue, N729 Doan Hall, Columbus, OH 43210, USA
e-mail: Kyle.perry@osumc.edu

complete surgical myotomy with a low rate of esophageal mucosal injury [19–21]. Short-term follow-up studies have demonstrated results similar to those seen with LHM, but long-term follow-up has not been reported [22, 23].

The objective of this study was to evaluate and compare the long-term outcomes of LHM and RHM, particularly the relief of dysphagia and development of significant postoperative gastroesophageal reflux symptoms. We hypothesized that RHM results in long-term surgical outcomes similar to those achieved with LHM.

Materials and methods

Patients

Between 1995 and 2006, 75 consecutive patients underwent minimally invasive Heller myotomy at The Ohio State University Wexner Medical Center using a standard laparoscopic ($n = 19$, 25 %) or robotic-assisted ($n = 56$, 75 %) approach. All patients presented with a primary complaint of dysphagia and were diagnosed with achalasia based on an esophagram, endoscopy, and esophageal manometry. Patient data are maintained in a database approved by our Institutional Review Board. Data points collected include age, gender, body mass index, ASA classification [24], operative indications, preoperative testing, operative time, intraoperative blood loss, length of hospital stay, and perioperative complications.

Operative approach

All patients were treated by LHM with or without robotic assistance as determined by surgeon preference. LHM was performed using a five-port technique. The phrenoesophageal ligament was divided, and the gastric fundus sufficiently mobilized to allow creation of a partial fundoplication. In all cases, an 8-cm myotomy was created on the anterior surface of the esophagus using electrocautery and extended at least 2 cm below the gastroesophageal junction. Patients underwent a 270° posterior (Toupet) fundoplication or anterior 180° (Dor) fundoplication for postoperative reflux control, as per surgeon preference.

Our technique of RHM was performed as previously described [19]. Briefly, the patient is positioned on a split-leg table, and the bedside component of the robot is positioned over the patient's left shoulder after accessing the abdomen through four ports. The patient is placed in the reverse Trendelenburg position, and the robot is docked to the ports. Two working ports are used with downward traction of the proximal stomach by the assistant. The esophagus is dissected, and an 8- to 10-cm esophageal myotomy is created using hook electrocautery. A posterior cruroplasty is performed as needed, followed by a partial fundoplication.

Follow-up

Overall, complete follow-up was available in 53 (71 %) patients, including 15 (79 %) following LHM and 38 (68 %) following RHM ($p = 0.78$). Eight patients died during the follow-up period from causes unrelated to their surgery, three following LHM and five following RHM. Telephone follow-up was attempted for the remaining 67 patients and was successful in 44 (66 %). The remainder declined to participate or could not be reached.

Long-term follow-up evaluation was performed via mail or telephone questionnaire. Outcomes of interest included recurrent dysphagia, GERD symptoms, and patient satisfaction with their operation. Dysphagia and heartburn were assessed using a five-point Likert scale, and post-myotomy disease-specific quality of life was assessed using the validated GERD health-related quality of life (GERD-HRQL) instrument [25]. Patient satisfaction with their operation was rated as satisfied, neutral, or dissatisfied, and patients were asked with the knowledge of hindsight if they would chose to have the operation again.

Statistical analysis

Data were tested for normality and presented as mean ± standard deviation or median (range), where appropriate. Statistical analysis was performed using Stata 12 (Stata Corp, College Station, TX). Analysis of continuous variables was performed using either the Student's t test or the Mann–Whitney U test, and the chi-square or Fisher's exact test was used to compare dichotomous variables, as appropriate. A p value <0.05 was considered statistically significant.

Results

Nineteen patients underwent LHM and 56 had RHM. All procedures were completed without conversion to laparotomy. Sixty-eight (90 %) patients underwent a Toupet fundoplication, while 5 (7 %) had a Dor fundoplication and 2 (3 %) patients early in the series did not have a fundoplication performed. Ninety-eight percent of RHM patients had a Toupet fundoplication performed compared to 68 % of LHM patients ($p < 0.01$, Table 1).

Patient characteristics did not differ between patients undergoing RHM and LHM (Table 1). Overall, patients had an average age of 47.5 ± 15.7 years with a mean body mass index of 26.1 ± 5.9 kg/m^2. Fifty-two percent of

Table 1 Demographics, preoperative symptoms, and operative approach for patients undergoing robotic Heller myotomy (RHM) and laparoscopic Heller myotomy (LHM)

	RHM ($n = 56$)	LHM ($n = 19$)	p value
Age (mean ± SD, years)	47.5 ± 16.4	47.8 ± 14.0	0.93
Male [No. (%)]	28 (50.0)	11 (57.9)	0.60
BMI (mean ± SD, kg/m^2)	26.3 ± 6.0	25.7 ± 5.6	0.74
ASA class [*No.* (%)]			
1–2	36 (66.7)	11 (78.6)	0.52
3–4	18 (33.3)	3 (21.4)	
Severe preoperative dysphagia [No. (%)]	56 (100)	19 (100)	1.00
Type of fundoplication [*No.* (%)]			
Toupet	55 (98.2)	13 (68.4)	<0.01
Dor	1 (1.8)	4 (21.1)	
None	0 (0)	2 (10.5)	

BMI body mass index, *ASA* American Society of Anesthesiologists physical classification system [24]

Table 2 Operative data for patients undergoing robotic Heller myotomy (RHM) and laparoscopic Heller myotomy (LHM)

	RHM ($n = 56$)	LHM ($n = 19$)	p value
Operative time (mean ± SD, minutes)	133 ± 29	121 ± 22	0.14
Operative blood loss [median (range), mL]	25 (25–400)	50 (25–200)	0.43
LOS [median (range), days]	1 (1–3)	2 (1–9)	<0.01
Intraoperative esophageal perforation [No. (%)]	0 (0)	3 (15.8)	0.01

patients were male. All patients presented with a primary symptom of dysphagia and rated this as severe.

Operative data are summarized in Table 2. The mean operative time for LHM was 121 ± 22 min compared to 133 ± 29 min for RHM ($p = 0.14$). Median intraoperative blood loss was 50 (25–500) mL for LHM and 25 (25–400) mL for RHM ($p = 0.43$). Intraoperative mucosal injury occurred in 16 % ($n = 3$) of patients undergoing LHM; there were no esophageal mucosal injuries during RHM ($p = 0.01$). There were no perioperative deaths in this series. The median length of stay was 2 (1–9) days following LHM and 1 (1–3) day following RHM ($p = 0.01$).

Long-term follow-up data were obtained with a median follow-up interval of 9.1 (3.9–14.8) years. Median follow-up interval following LHM was 9.9 (4.4–14.8) years and 9.1 (3.9–12.8) following RHM ($p = 0.49$). All patients reported adequate relief of their dysphagia following surgical myotomy, and median dysphagia score at long-term follow-up was two compared to five at baseline ($p = <0.01$). Eighty percent of patients reported enduring relief of their dysphagia without further intervention, including 70 % following LHM and 84 % after RHM ($p = 0.38$). Eight patients required postoperative intervention for recurrent symptoms, including three following LHM and five after RHM ($p = 0.38$). Seven underwent an endoscopy with balloon dilation (three after LHM and four following RHM), two in the LHM group had postoperative botulinum toxin injection, and one patient in each group underwent a second Heller myotomy. One patient with significant postoperative dysphagia following RHM required both balloon dilatation and botulinum toxin injection and subsequently required a redo LHM. Two patients in the LHM group ultimately required esophageal resection for end-stage achalasia 60 and 77 months after their initial surgical treatment.

Table 3 Long-term symptomatic outcomes of robotic Heller myotomy (RHM) and laparoscopic Heller myotomy (LHM)

	RHM ($n = 33$)	LHM ($n = 11$)	p value
Follow-up interval [median (range), months]	9.1 (3.9–12.8)	9.9 (4.4–14.8)	0.49
Dysphagia [*No.* (%)]			
Absent or mild	26 (79)	8 (80)	1.00
Moderate or severe	7 (21)	2 (20)	
Heartburn [*No.* (%)]			
Absent or mild	26 (79)	9 (90)	0.66
Moderate or severe	7 (21)	1 (10)	
PPI use [No (%)]	18 (56.3)	8 (80 %)	0.27
GERD-HRQL score [median (range)]	11 (0–36)	12 (6–20)	0.55
Satisfied [No. (%)]	32 (95.5)	10 (90.9)	0.44
Heller again [No. (%)]	30 (90.9)	10 (90.9)	1.00

Postoperative symptoms and medication use are summarized in Table 3. Overall, 62 % of patients report daily proton pump inhibitor (PPI) therapy at long-term follow-up, including 80 % following LHM and 56 % after RHM ($p = 0.27$). Heartburn symptoms were reported as minimal or absent in 90 % of patients following LHM and 79 % of patients following RHM ($p = 0.66$). Median GERD-HRQL score was 12 (6–20) following LHM compared to 11 (0–36) after RHM ($p = 0.55$). In both groups combined, the median GERD-HRQL score was 11 (0–23) for those not taking daily PPI therapy and 11 (0–36) for those on a PPI.

Overall, 95 % of patients were satisfied with their operation, including 91 % of LHM patients and 97 % of RHM patients ($p = 0.44$, Fig. 1). When asked to reconsider their treatment options given the benefit of hindsight,

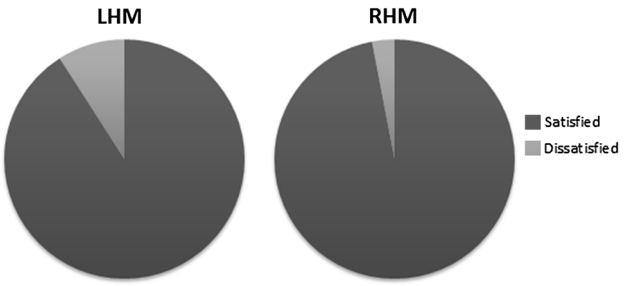

Fig. 1 Pie chart showing patient satisfaction in patients following laparoscopic Heller myotomy (LHM) and robotic Heller myotomy (RHM)

91 % of LHM and RHM patients ($p = 1.00$) said they would choose Heller myotomy again.

Discussion

The aim of this study was to evaluate the long-term results of RHM compared to those achieved with LHM. We found that RHM provided long-term dysphagia relief in the vast majority of patients and is associated with a high degree of patient satisfaction. A significant proportion of patients in both groups developed symptoms of gastroesophageal reflux, which requires daily acid suppression therapy, but few have significant breakthrough symptoms while taking acid-reducing medications. Overall, RHM produces long-term outcomes that are similar to those achieved with LHM, with a lower rate of intraoperative esophageal injury.

RHM has gained popularity during the past decade owing to improved visualization and manual dexterity. Studies of perioperative outcomes have demonstrated reasonable operative times, low morbidity, and the ability to create a complete surgical myotomy with a lower rate of esophageal mucosal injury than LHM [19–21]. Short-term follow-up studies have demonstrated dysphagia relief and patient satisfaction rates comparable to those reported for LHM, but long-term follow-up studies have not been reported [22, 23].

In this series of 56 RHM with a median follow-up interval of 9 years, we found similar perioperative results with a significantly lower intraoperative esophageal perforation rate compared to patients undergoing LHM. RHM was also associated with a significantly decreased length of hospital stay, although this likely relates to the fact that most of the LHM in this series occurred early in this institution's experience with Heller myotomy, as well as the increased mucosal injury rate which resulted in longer hospital admissions. While there may be some learning curve effect associated with the esophageal injury rate, improved visualization and manual dexterity seen with the robotic system likely contribute to the absence of intraoperative mucosal injury in patients undergoing RHM.

Long-term studies of open approaches to surgical myotomy have suggested declining success rates over time due to both recurrent dysphagia and the development of significant gastroesophageal reflux. In a comprehensive review of 149 patients undergoing Heller myotomy with Toupet fundoplication via laparotomy, Ortiz et al. [26] showed satisfactory results in 90 % of patients after 5 years, but this decreased to 75 % at 15-year follow-up due to recurrent dysphagia (11 %) or reflux symptoms (14 %). Other studies have shown that a progressive decline in results may occur following transthoracic or transabdominal surgical myotomy with or without fundoplication [27–30]. These studies demonstrate gradually increasing rates of recurrent dysphagia during the follow-up period and long-term pathologic reflux rates ranging from 13 to 64 %.

While long-term follow-up data for LHM are emerging, early studies have shown similar findings that early success may not adequately predict long-term outcomes. Bloomston et al. [31] demonstrated significantly increased rates of dysphagia (47 % vs. 11 %) and heartburn (48 % vs. 31 %) 3 years following LHM with Dor fundoplication compared to 1 year after surgery. A European single-center cohort study examined the outcomes of 407 consecutive LHM, with 177 available with at least 5-year follow-up data. They achieved complete resolution of dysphagia in 87 % of patients after 5 years and 82 % 10 years following LHM [16]. These results clearly underscore the need for long-term follow-up of these patients, including evaluation of new treatment approaches and surgical techniques.

Several studies have evaluated durability of dysphagia relief and patient satisfaction several years following LHM with reintervention rates ranging from 6 to 20 % (Table 4) [13–17]. The present study demonstrates complete resolution of dysphagia without need for endoscopic or operative reintervention in 84 % of patients and an overall patient satisfaction rate of 97 % for RHM at a median follow-up interval of 9 years. Jeansonne et al. [13] evaluated 17 patients with a median follow-up interval of 11 years and found satisfactory results in 84 % of patients with 47.1 % of patients reporting absence of dysphagia and 47.1 % describing only mild persistent dysphagia. Three (17 %) patients required retreatment for severe dysphagia, and 94 % of patients were satisfied with their operation. In another study of 47 patients with a median follow-up interval of over 10 years, Cowgill et al. [15] demonstrated long-term dysphagia relief in >90 % of patients with a low rate of subsequent endoscopic or surgical intervention.

While resolution of dysphagia is the primary goal of any achalasia therapy, the development of significant

Table 4 Previous studies reporting at least 6-year follow-up of laparoscopic Heller myotomy for achalasia

Primary author	Year	Patients (No.)	Follow-up (years)	Absent or mild dysphagia (%)	Retreatment (%)	Mild to mod heartburn (%)	PPI use (%)	Satisfaction (%)
Cowgill [15]	2009	47	10.6	92	12.8	NR	NR	92
Jeansonne [13]	2007	17	11.2	94	17.7	23.5	NR	94
Kilic [14]	2009	46	6.4	80	20	NR	NR	NR
Sasaki [17]	2009	34	7.8	100	5.9	0	NR	NR
Zaninotto [16]	2008	177	10.0	82	9.6	NR	NR	NR

gastroesophageal reflux symptoms following surgical myotomy remains a significant concern for both physicians and patients. Reported reflux rates following open myotomy range from 13 to >60 % [27–30]. While the reporting of reflux symptoms and PPI usage at long-term follow-up following LHM has been inconsistent, heartburn may occur in a significant proportion of patients. Increased esophageal acid exposure has been demonstrated in 21 % of patients following Toupet fundoplication and 42 % following Dor fundoplication even at early postoperative follow-up [31, 32].

In this series, 62 % of patients required daily PPI therapy to control heartburn symptoms in the long term. The vast majority, however, were successfully managed with medical therapy and achieved adequate dysphagia relief without significant GERD symptoms refractory to medical therapy. This is reflected in the equivalent GERD-HRQL scores reported by patients who required PPI therapy and those who did not. While the data regarding long-term GERD symptoms and management are limited, these results are congruent with the reported literature for LHM [13]. While the rate of PPI responsive heartburn is very high, objective pH testing would be useful to differentiate symptoms due to pathologic acid reflux from those caused by stasis of material in the distal esophagus caused by esophageal dysmotility.

Conclusion

RHM provides long-term dysphagia relief in the vast majority of patients and is associated with a high degree of patient satisfaction and a low rate of esophageal mucosal injury. While a significant proportion of patients develop symptoms of gastroesophageal reflux requiring daily acid suppression therapy, few have significant breakthrough symptoms while taking acid-reducing medications. Larger long-term follow-up studies with subjective and objective assessments of esophageal function and acid reflux are required to further establish the long-term outcomes of achalasia treatments.

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