J Minim Invasive Surg Sci. 2016 November; 5(4):e41196.
doi: 10.17795/minsurgery-41196.

Published online 2016 October 5.

Review Article

Learning Curves in Robotic Rectal Cancer Surgery: A literature Review

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Received 2016 August 01; **Revised** 2016 September 26; **Accepted** 2016 September 28.

Abstract

Background: Laparoscopic rectal cancer surgery offers several advantages over open surgery, including quicker recovery, shorter hospital stay and improved cosmesis. However, laparoscopic rectal surgery is technically difficult and is associated with a long learning curve. The last decade has seen the emergence of robotic rectal cancer surgery. In contrast to laparoscopy, robotic surgery offers stable 3D views with advanced dexterity and ergonomics in narrow spaces such as the pelvis. Whether this translates into a shorter learning curve is still debated. The aim of this literature search is to ascertain the learning curve of robotic rectal cancer surgery.
Methods: This review analyses the literature investigating the learning curve of robotic rectal cancer surgery. Using the Medline database a literature search of articles investigating the learning curve of robotic rectal surgery was performed. All relevant articles were included.
Results: Twelve original studies fulfilled the inclusion criteria. The current literature suggests that the learning curve of robotic rectal surgery varies between 15 and 44 cases and is probably shorter to that of laparoscopic rectal surgery.
Conclusions: There are only a few studies assessing the learning curve of robotic rectal surgery and they possess several differences in methodology and outcome reporting. Nevertheless, current evidence suggests that robotic rectal surgery might be easier to learn than laparoscopy. Further well designed studies applying CUSSUM analysis are required to validate this motion.

Keywords: Learning Curve, Robotic, Rectal Surgery, Rectal Cancer

1. Introduction and Aim

The introduction of the minimally invasive approach to colorectal surgery brings forth an era of potentially better surgical outcomes, shorter recovery time, and greater surgical dexterity (1). Laparoscopic and open surgery for colorectal disease has already been shown to have equivalent outcomes with regards to disease recurrence, and metastasis with an associated significantly quicker recovery time with laparoscopic surgery (2, 3). However, this established benefit with laparoscopy comes at a cost of a steep learning curve (4-6).

Robotic assistance, first utilised in 2001, seeks to further the premise of minimally invasive surgery. The hope is of a shorter learning curve through means of greater technical precision, greater degrees of freedom, and better visualisation using 3 dimensions as compared to laparoscopy. These technical advantages become even more beneficial in the tight confines of the pelvis. A handful of studies that compare the efficacy of robotic assisted total mesorectal excision with a purely laparoscopic approach illustrate that both approaches were mostly comparable (including postoperative morbidity and mortality, lymph nodes harvested, and duration of hospital stay) with the robotic approach also being associated with a lower conversion rate and more favorable resection margins (7-9).

Since the first robotic colectomy in 2002 (10), a number of case series and prospective studies have proven the feasibility and safety of this approach, as shown by Xiong et al. (7) in his meta-analysis. The robotic system provides a stable platform with 3 dimensional views, which help in precise dissection in a narrow surgical field. The Endowrist® instruments are designed to provide an extraordinary range of motion and improved dexterity (11). Furthermore, the surgeon-controlled camera, ergonomic setting console, steady and precise traction are also potential benefits of the robotic system (12, 13).

The robotic approach has become an attractive option to colorectal surgeons despite current data being limited. Therefore, more data is needed to establish the true superiority of robotic surgery over the laparoscopic approach (9, 12, 14).

There are a number of challenges associated with the robotic approach. These include lack of tactile sensation and tensile feedback, high cost, mentorship and a steep learning curve (13, 15-18).

Currently, robot-assisted colorectal surgery is conducted only in a small number of centres worldwide, usually by surgeons of vast prior open and laparoscopic experience. The aim of this literature search is to ascertain the learning curve of robotic-assisted rectal surgery. Once known, we will be better placed to comment on the feasibility of more widespread robot-assisted surgery.

2. Methods

A Medline electronic database search was performed in September 2015. The following search terms were applied: "learning curve" AND "robotic" OR "da Vinci" AND "rectal cancer" OR "colorectal cancer". All original studies examining the learning curve of robotic rectal surgery were included in this study, whether the procedures were fully robotic or hybrid in nature. Studies that did not include the use of a robot were not included. The reference lists of the included studies were manually searched to identify any further relevant articles. A flow diagram of the selection process is shown in Figure 1.

Twelve studies in total matched the inclusion criteria, all from the last 10 years. Nine of these studies analysed data solely from rectal cancer patients whereas three studies looked at data from both benign and malignant rectal disease patients. In all studies bar one, surgery was conducted by one surgeon, usually with vast experience. Data in 5 out of 12 studies was collected retrospectively (Table 1).

2.1. Outcome Assessment

Learning curves can be determined using parameters such as operating times, lack of complications, and lack of conversions, or a combination of these. Typically operating time has most commonly been used as a proxy to assess competency or proficiency. Some studies simply assess the trends between halves or quartiles, but more recently many studies have been using the cumulative sum (CUSUM) method for assessing trends.

The CUSUM method is an effective way of monitoring performance over time and analyzing trends; it has been used for this purpose since the 1970s (19). The CUSUM of operating time represents the difference between the cumulative sum of all individual values up to a specified point and mean of all data points. Therefore, the CUSUM for the first data point is the difference between that point and the average of all points, and the CUSUM after the 2nd data point is the difference between the value of the 2nd point and the mean of all points added to the cumulative sum of previous points that has been carried forward.

In 6 of 12 studies included in this review, learning curves were ascertained by using the CUSUM of the operating time (Table 1). Two of these 6 studies went further to calculate also the risk-adjusted CUSUM (RA-CUSUM), which allows comparison of actual risk with expected risk. The remaining 6 out of 12 studies did not use the CUSUM method for operating time but instead split their cohorts and assessed operating times and other outcomes in each section or used a single hybrid variable comprising of different variables including operative time, conversion, perioperative morbidity and circumferential margin to measure the progress (28) (Table 1).

3. Results

In those studies using the CUSUM (operative time) method, the learning curves for robot assisted surgery for both neoplastic and non-neoplastic indications were between 15 - 44 and 21 - 44 respectively (Table 1). The learning curve is usually regarded as the number of cases needed to achieve initial competency where operative time, complication rates, and outcomes have stabilised. Most studies described three distinct learning curves, with phase 1 usually regarded as the early learning phase, phase 2 as the competent phase, and phase 3 where the surgeon takes on the most difficult cases. One study described only 2 phases, an initial period of learning up to case number 22, with no subsequent significant deviations in parameters after that (24).

The CUSUM method allows graphical visualisation of sum of operative times after any number of operations in relation to the average operation time. (Thus a section of the graph where the line starts above the above average line and continues to slope upwards indicates a phase of the learning where average operative time is higher than average and is continuing to increase). Despite the common ground of 3 distinct learning phases in many studies, the morphology of the CUSUM graphs seems to vary greatly between studies. In two studies the graph roughly adopts a straightforward upwards parabola, indicating a period of increasing operative times initially until proficiency was gained at which point operative times started to decrease again (26, 29). Furthermore, in another 2 studies, the CUSUM graphs show initial downward curve with subsequent upward curves (22, 23). This would indicate a short period where operative times were quickly improving followed by a period where operative times increased again (presumably when more difficult cases were attempted), and finished off by another period of shortening operative times. The CUSUM graph for another study showed a straightforward downwards parabola, indicating operative times initially quickly improving and then gradually getting longer (presumably as more difficult cases are attempted) (19). D'Annibale et al. (24), the only study to report 2 learning phases, showed only an initial learning period on its graph.

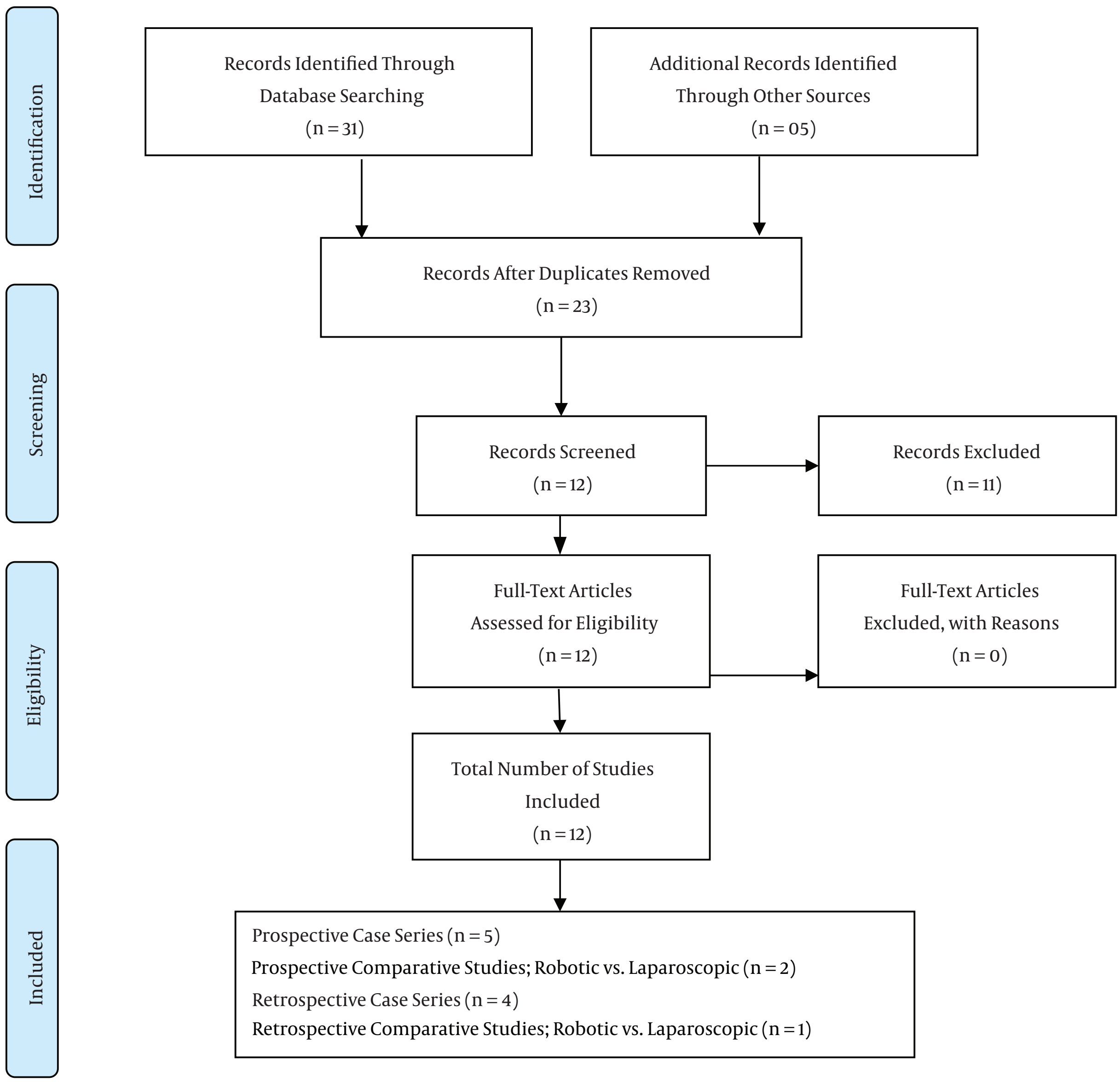

Figure 1. Selection Process Flow Diagram

The variability in indication for surgery, the type of surgery, the perceived difficulty of surgery, and the evolution of these 3 factors over the course of the studies involved is likely to account for the heterogeneous morphologies of CUSUM curves. Despite these varied morphologies, all, except one study, state 3 distinct learning phases (Table 1). The raw operative times, where stated as a mean, were similar between these studies and ranged from 197.4 - 278.7 minutes (19, 22, 23, 26, 29). Operative times in studies not using CUSUM were 197.7 - 720.0 minutes (20, 21, 27, 28, 30).

The 2 studies that also looked at RA-CUSUM showed interesting results. Park et al. (26) used 5 different parameters to determine "surgical success" in their study; essentially this equated to the absence of complications or conversion. They showed the time at which RA-CUSUM was at its lowest (i.e. success at its peak) correlated almost exactly with the second peak of CUSUM of operating time; probably a period where proficiency in straightforward cases was gained and on the cusp of attempting more difficult cases (26). They used this fact to demarcate the second and third learning curve (26). Whereas, Jimenez et al. (23)

Table 1. Relevant Publications for Learning Curves in Robotic Rectal Surgery

Author & Year	Study Type	Number of Patients	Modality / Technique	Statistics Used	Learning Curve	No. of Surgeons	No. of Phases	Procedure (= n)
Bokhari et al. (19) (2011)	Retrospective	50	Robotic/ hybrid	CUSUM	15	Single	3	AR 25; LAR 15; APR 6; RP 4
Akmal et al. (20) (2012)	Retrospective	80	Robotic/ hybrid	N/A	40	Single	2	Cancer only LAR 40, CA 21; APR 19
Kim et al. (21) (2012)	Prospective	62	Robotic/ totally	N/A	20	Single	N/A	Cancer only APR 1; LAR 50; Ultra LAR 10; Hartmann's 1
Sng et al. (22) (2013)	Retrospective	197	Robotic/ totally	CUSUM	35	Single	3	Cancer only AR 3; LAR 126; Ultra LAR 10; ISR 45; AP 13
Jimenez-Rodriguez et al. (23) (2013)	Prospective	43	Robotic/ totally	CUSUM, RA-CUSUM	21-23	Three	3	Cancer only AR 36; APR 7
D'Annibale et al. (24) (2013)	Prospective	100	Robotic/ totally	CUSUM	22	Single	2	Cancer only (Robotic = 50, Laparoscopic = 50) LAR (TME) 100
Byrn et al. (25) (2014)	Retrospective	85	Robotic-assisted	N/A	N/A	Single	N/A	LAR 29; APR 21; Other 35
Park et al. (26) (2014)	Prospective	130	Robotic/ Hybrid	CUSUM, RA-CUSUM	44	Single	3	Cancer only LAR 130
Kuo et al. (27) (2014)	Retrospective	64	Robotic/totally	N/A	19	Single	2	Cancer only (robotic = 36, Laparoscopic = 28) ISR for low rectal cancer
Kim et al. (28) (2014)	Prospective	167	Robotic/hybrid	N/A	32	Single	3	Cancer only AR (TME) for rectal cancer
Yamaguchi et al. (29) (2015)	Prospective	80	Robotic/ totally	CUSUM	25	Single	3	Cancer only AR 6; LAR 46; ISR 22; APR 6
Melich et al. (30) (2015)	Prospective	198	Robotic/ totally	N/A	41	Single	N/A	Cancer only (robotic = 92, laparoscopic= 106) LAR 92

Abbreviation: CUSUM, cumulative sum method; RA-CUSUM, risk-adjusted CUSUM; AR, anterior resection; LAR, low anterior resection, RP, rectopexy; CA, colo-anal; APR, abdomino-perineal resection, ISR; intersphincteric resection; TME, total mesorectal excision.

concluded that there was no overall trend in complication rates as surgical experience increased.

There were 6 studies that did not use the CUSUM (operative time) method for determining learning curves. Akmal et al. (20) split their 80 cases into two groups and found no difference in the operative times or complication rates of the two groups. Byrn et al. (25) on the other hand, found a significant difference in operative times between their two halves (267 vs. 224 minutes) but no difference in complication or conversion.

Kim et al. (2012) (21) evaluated the learning curve for achieving expertise in robotic surgery based on operative time and short term outcomes including postoperative complications, need for transfusion, conversion to open surgery, hospital stay and time to soft diet. All surgeries were done by a single surgeon primarily trained in open technique. They concluded that an experienced open surgeon with limited experience can perform robotic rectal surgery safely without a long learning curve (21) (Table 1).

Kuo et al. (27) studied the clinical outcomes of robotic-assisted intersphincteric resection (ISR) for low rectal cancer. The salient learning curve evaluation parameters included estimated blood loss, need for diverting colostomy, length of hospital stay, time to pass first flatus, time to normal diet, distal resection margin and number of lymph nodes retrieved. They concluded that robot-assisted ISR is feasible and safe with no compromising oncological outcomes (27) (Table 1).

Kim et al. (2014) (28) used a single hybrid variable including operative time, conversion, perioperative morbidity, and circumferential margin to measure the learning curve and success of robotic total mesorectal excision (TME) for rectal cancer. They concluded that the learning process for robotic TME predominantly affected the first 32 cases (28) (Table 1). They also observed that the operative time decreased over 3 phases (28).

Melich et al. (30) uniquely studied the learning curves for laparoscopic and robotic surgery simultaneously for low anterior resections (LAR) for rectal cancer. All operations were performed by a single surgeon primarily trained in open rectal surgery. Ninety two robotic cases were analyzed. Operative time and other parameters including major complications, resection margin involvement, conversion rate, lymph node harvest and estimated blood loss were used to define the learning curves. They concluded that initial robotic operative times improved with practice and eventually became faster than those for laparoscopic surgery after the first 41 cases (30) (Table 1).

There was a varied case mix between the studies both in terms of indication for surgery and type of rectal surgery. The most common procedure performed was a low anterior resection (LAR). The two studies with the steepest learning curves also had the highest proportions of lower anterior resections, though this can only be seen as an observation rather than a definite correlation (22, 26). Park et al. (26) quite rightly pointed out that their cohort is more homogenous than those of other studies as they attempted only low anterior resection with a purely robotic approach, unlike the heterogeneous cohorts of the other studies. This would lend validity to their learning curve estimate (26). It is difficult to make any other observations with regards to type of surgery performed in such a small number of studies. We have insufficient data to make any comment on whether prior surgical experience has any effect on robotic learning curve, though it is noted that the study with the surgeon who had most prior robotic surgical experience (5.5 years) in fact stated the steepest learning curve (26). All studies were performed in the last 10 years and it is unlikely that any differences in surgical instrumentation would have made any significant difference to the learning curve.

4. Discussion

Current published evidence suggest that the learning curves for robotic assisted rectal cancer surgery vary between 15 - 44 and are probably shorter than the learning curves for laparoscopic rectal surgery (figures ranging from 30 - 70) (4-6).

Equal outcomes have been shown for total mesorectal excision in a meta-analysis comparing robotic and laparoscopic surgery with some parameters such as conversion rate and resection margin favoring robotic surgery (7). Given these factors, there seems a reasonable case for adopting the robotic technique in rectal resection surgery. The overall additional benefits of marginally better outcomes and possibly shorter learning curves will have to be carefully evaluated against the high initial capital cost.

Many centers that undertake robot-assisted colorectal surgery at the moment actually utilize hybrid techniques that necessitate vast prior laparoscopic experience. One study that looked at whether a straight switch from open surgery to robotic surgery could be made, found that it was indeed possible. The clinico-pathological outcomes of two surgeons, one with 30 prior laparoscopic procedures and the other with 300 laparoscopic procedures, who were robotic surgery novices showed no difference and mean operative time was actually shorter in the surgeon with less laparoscopic experience (31). However, this is a single study looking at two individuals and it is possible that 30 laparoscopic procedures may have been enough to develop the necessary transferrable skills in that particular case.

Another important consideration is the standardization of operative technique to facilitate learning, certainly through the initial period of training (32). An assessment based program to help learn robotic total mesorectal excision surgery is underway through the European faculty at EARCS. Teaching and training through bodies like EARCS would help bridge the skill gaps that exist at present.

5.1. Conclusions

There are only a small number of studies assessing the learning curve of robotic rectal surgery to date. Method of assessment, study design and results are inconsistent between the current available studies. Nevertheless, current evidence suggests that the learning curve of robotic rectal surgery is probably shorter than that of laparoscopic rectal surgery. Further studies applying CUSUM analysis would allow us to better assess the learning curve of robotic rectal surgery. In addition, studies examining the learning curves of multiple surgeons would strengthen the validity of their results. Standarisation of operative technique could further reduce the learning curve of robotic TME surgery.

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