Robotic assistance in ventral hernia repair may decrease the incidence of hernia recurrence

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Background: Since the advent of laparoscopic surgery, many studies have shown the advantages of laparoscopic surgery over open surgery for ventral hernia repair (VHR). As robotic surgery is gaining popularity, we sought to compare the outcomes of this newer robotic-assisted technique to the outcomes of established open and laparoscopic techniques to assess for any additional benefit.

Methods: A meta-analysis research design was employed. Multiple databases were queried for publications over the past 10 years and 23 articles were selected based on pre-determined selection criteria. Data were extracted and the arm-based network meta-analysis method was utilized to examine the effect difference for the three arms of our study: Open, laparoscopic and robotic-assisted VHR.

Results: As expected, laparoscopy had an advantage over open VHR in terms of infection rates. This advantage was also observed in the robotic group over the open group; however, there was no statistical difference between the laparoscopic and robotic groups when infection rates were compared head-to-head. The robotic group had a significant advantage over both the open and more importantly, the laparoscopic groups in recurrence rates.

Conclusions: The results of this study suggest that robotic surgery maintains some of the advantages of laparoscopic surgery and may also provide the additional advantage of recurrence rate reduction. This may be explained by the ability to perform a more complex hernia repair with robotic assistance secondary to the ease of closure of the fascial defect. More research is needed to validate this finding.

Keywords: Hernia recurrence, outcomes, robotic, ventral hernia repair

INTRODUCTION

Ventral hernia repair (VHR) is one of the most commonly performed general surgery procedures in the United States. Since the first laparoscopic VHR in the early 1990s, multiple studies have shown the advantages of laparoscopic over open VHR, particularly decreased hospital length of stay and lower instances of surgical site infections. However, studies have also shown increased rates of serious complications with laparoscopic VHR such as enterotomy, especially in cases with significant lysis of adhesions. Given conflicting data, it is understandable that laparoscopic VHR has not become the standard of care as laparoscopy has in other routine surgeries, such as cholecystectomy.

The recent addition of robotic VHR has added an additional facet to this continued discussion. While early
studies have shown that robotic VHR is safe and effective, studies vary widely in outcomes measurements. This ranges from negative views of increased cost and operative time with no benefit to decreased recurrence and easier suturing for complex repairs.

As this debate continues, it is important to note that no large study comparing open, laparoscopic, and robotic VHRs has been completed. The aim of this study was to compare the outcomes of open, laparoscopic and robotic VHRs.

METHODS

After defining the research question, we elected to use a meta-analysis research design. Data was extracted from articles selected using PubMed, Embase, Web of Science Core Collection and the full-text journal subset of ClinicalKey databases. An initial article search was performed on 20 March, 2017. The search was limited to studies on human subjects which were published in English from 1 January, 2011, to 31 December, 2017. Articles were identified in PubMed, Embase and Web of Science Core Collection by using the following terms: (post-operative outcomes open VHR), (post-operative outcomes laparoscopic VHR), (open VHR), (laparoscopic VHR) and (robotic-assisted VHR). After excluding duplicates, 157 relevant articles were identified for further review [Figure 1].

Criteria were established to narrow the articles to include only those which were pertinent to the research question. The patients in the studies had to have undergone VHR

![Figure 1: Search strategy flowsheet. The 23 studies from which the data were extracted and analysed were identified using an initial search for all three methods of ventral hernia repair followed by a subsequent search for robotic ventral hernia repair. Overlapping studies were excluded. Article selection was based on strict inclusion and exclusion criteria](image-url)
with mesh in order to be included. Included studies also reported raw outcomes data, were not focussed on particular aspects or techniques of VHR, and utilised broad demographics of patients that were not limited by age or body mass index. Three individuals were selected to screen the articles using these guidelines and to subsequently extract all available data. Twenty articles were identified and evaluated for potential overlap based on the periods and databases used in each study. No significant potential patient overlap was found.

After extracting preliminary data, the robotic-assisted arm contained only 719 patients which was nearly one hundred time smaller than both the laparoscopic and open arms. Therefore, to generate additional power in the robotic-assisted arm, another search was performed on 8 December, 2017, for articles published over the past 10 years on outcomes after robotic VHR. It was unnecessary to expand the open and laparoscopic arms given the large number of patients in each. The previously mentioned databases were again queried, and relevant articles were found using PubMed, Embase and ClinicalKey databases. The following terms were used robotic-assisted VHR and robotic-assisted VHR NOT open NOT laparoscopic. In addition, when searching in PubMed the following medical subject heading terms were used ‘Hernia, Ventral’ and ‘Robotic Surgical Procedures’. This search provided an additional 11 articles, 3 of which fit inclusion criteria and were used in our research bringing the total of included articles to 23.

After completing data extraction, the arm-based network meta-analysis method was utilised to examine the effect difference for the three arms of our study: Open, laparoscopic and robotic-assisted VHR. Network meta-analysis integrates both direct and indirect evidence in all articles. Significant differences were presented with odds ratios (ORs) and 95% confidence intervals, which did not contain 1. All statistical analyses were established in the R version 3.4.3, package ‘pnetmeta’ (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The quality of the included studies was assessed using the Oxford Centre of Evidence-Based Medicine Levels of Evidence. The one randomised controlled trial in our study was first assessed based on the Jadad score in which the randomisation, the process for blinding, and the description for dropouts are used to generate a score from 0 (low quality) to 5 (high quality). Based on these criteria, the randomised controlled trial was given an Oxford grade of 2B as it was not blinded. The retrospective comparative studies were assessed using the Newcastle-Ottawa quality assessment scale. These were given Grades 2B and 3B depending on whether the design was that of a case-control or cohort. All case series were designated as Grade 4.

After extracting data from all 23 articles, there were 135,743 patients in the open arm, 71,912 patients in the laparoscopic arm and 1282 patients in the robotic arm [Table 1]. Results of ORs with 95% confidence interval with pairwise comparisons for the seven outcomes can be seen in Table 2. There was no significant difference in outcomes between open, laparoscopic and robotic VHR when comparing seroma/haematoma, enterotomy, ileus, urinary retention or mortality.

Consistent with prior studies, there was a significant decrease in surgical site infection rates when comparing laparoscopic to open VHR, as well as robotic, assisted to open VHR (OR lap vs. open 0.44 [0.29–0.66] and OR robot vs. open 0.30 [0.08–0.81]). However, there was no difference in surgical site infection rates when comparing laparoscopic and robotic-assisted VHR head-to-head (OR robot vs. lap 0.68 [0.19–1.80]). Both laparoscopic- and robotic-assisted techniques utilise smaller incision which may, in part, account for these decreased infection rates.

In addition, there was a statistically significant reduction in recurrence with robotic VHR compared to both laparoscopic and open VHR (OR robot vs. lap 0.33 [0.09–0.91] and OR robot vs. open 0.32 [0.07–0.93]). This had been recognised in prior studies that evaluated recurrence and ease of intra-operative suturing for fascial closure, but no large studies have been completed, and hence there was often no statistical significance. Utilising a network-based meta-analysis we were able design a study with enough power to detect a difference.

DISCUSSION

The low utilisation of laparoscopic VHR is multifactorial and likely includes surgeon factors such as inexperience and lack of training in laparoscopy. Perhaps, more importantly, there are also patient and hernia specific factors that dissuade surgeons from performing laparoscopic VHR such as previous abdominal surgeries and hernia size. Port sites become areas of potential future hernias. Some studies have shown increased operative times with laparoscopy, which may be especially true when extensive lysis of adhesions is performed. Studies have also shown an increased risk of enterotomy, which can be associated with port placement and adhesions.
Robotic assistance in VHR may help overcome some of the shortcomings of laparoscopic surgery while maintaining the many benefits of minimally invasive surgery. Although to the best of our knowledge, no large randomised controlled trials comparing robotic VHR to laparoscopic or open repair have been published, our network meta-analysis showed an infection rate comparable to that of laparoscopic VHR [Table 3]. Readmission rate and length of stay are also similar to laparoscopic outcomes.\textsuperscript{[12,13]}

The advantages of robotic VHR stem in part from the dexterity that is offered by a robot. This allows for more complex hernia repairs including those in which the peritoneal cavity is never entered. Lysis of adhesions performed while using three-dimensional technology may also be easier and safer,\textsuperscript{[12]} though this was not confirmed with our study. Three-dimensional visualisation, as well as increased dexterity, may also result in a decreased conversion rate to open procedures as some studies have found.\textsuperscript{[13]}

The results of our study suggest that hernia recurrence may be reduced using a robotic repair as compared to both laparoscopic and open repairs. Hernia recurrence has not only been shown to decrease a patient's quality of life, but\textsuperscript{[9]} it can also result in reoperation and increased health-care costs. The reduction in recurrence that results from a robotic VHR is thought to be due to primary closure of the hernia defect in addition to mesh placement and circumferential suture fixation of the mesh.\textsuperscript{[14]} Primary closure of the defect results in a more even distribution of tension across the abdominal wall.\textsuperscript{[13]} The reduction in infection that has been attributed to smaller incisions may also play a role in decreased robotically repaired hernia recurrence.

While robotic surgery shows promise as a major contributor to future improvements in VHR outcomes, current usage is limited by increased operative times and cost.\textsuperscript{[1,12,13]} In a recent case series published in 2017, Chen et al. reported that their operative time for the robot-assisted group was 156.6 min compared to 65.9 min for the laparoscopic group.\textsuperscript{[15]} Increased operating times translates to the increased cost to hospitals. This is in addition to the initial purchasing fees of the robot and software as well as annual maintenance fees and the repeated cost of

### Table 1: Overview of included studies

| Reference      | Level of evidence | Design           | Duration of the study (years) | Number of open | Number of laparoscopic | Number of robotic |
|----------------|-------------------|------------------|-------------------------------|----------------|------------------------|-------------------|
| Aher et al., 2015\textsuperscript{[4]} | 3B                | Retrospective comparative | 4                             | 90,721         | 26,286                 |                   |
| Ahonen-Siirtola et al., 2015\textsuperscript{[1]} | 3B                | Retrospective comparative | 7                             | 291            | 527                    |                   |
| Asti et al., 2016\textsuperscript{[5]} | 3B                | Retrospective comparative | 5                             | 70             | 54                     |                   |
| Bianco et al., 2016\textsuperscript{[6]} | 4                 | Case series       | 4.25                          |                |                        | 95                |
| Bittner et al., 2018\textsuperscript{[7]} | 2B                | Retrospective comparative | 1.7                           | 76             | 26                     |                   |
| Cassie et al., 2014\textsuperscript{[8]} | 2B                | Retrospective comparative | 2                             | 13,109         | 1543                   | 39                |
| Chen et al., 2017\textsuperscript{[9]} | 2B                | Retrospective comparative | 3                             | 33             | 39                     |                   |
| Coakley et al., 2017\textsuperscript{[10]} | 3B                | Retrospective comparative | 5.2                           | 32,243         | 351                    |                   |
| Colavita et al., 2012\textsuperscript{[11]} | 2B                | Prospective comparative | 3.8                           | 402            | 308                    |                   |
| Davies et al., 2012\textsuperscript{[12]} | 2B                | Retrospective comparative | 2                             | 110            | 158                    |                   |
| Dheri et al., 2015\textsuperscript{[13]} | 2B                | Retrospective comparative | 3                             | 116            | 111                    |                   |
| Ecker et al., 2016\textsuperscript{[14]} | 3B                | Retrospective comparative | 5                             | 9228           | 4339                   |                   |
| Ecker et al., 2013\textsuperscript{[15]} | 2B                | Randomised clinical trial | 7.6                           | 100            | 94                     |                   |
| Gherardi et al., 2013\textsuperscript{[16]} | 4                 | Case series       | 10                            |                | 118                    |                   |
| Gonzalez et al., 2017\textsuperscript{[17]} | 4                 | Case series       | 3.6                           |                | 368                    |                   |
| Huang et al., 2013\textsuperscript{[18]} | 4                 | Case series       | 3.7                           |                | 100                    |                   |
| Koutsanis et al., 2013\textsuperscript{[19]} | 2B                | Retrospective comparative | 2                             | 21,463         | 5303                   |                   |
| Kudzi et al., 2015\textsuperscript{[20]} | 4                 | Case series       | 3                             |                | 106                    |                   |
| Kumar et al., 2015\textsuperscript{[21]} | 4                 | Case series       | 4                             |                | 53                     |                   |
| Langbach et al., 2015\textsuperscript{[22]} | 4                 | Case series       | 10.25                         | 73             | 82                     |                   |
| Liang et al., 2013\textsuperscript{[23]} | 2B                | Case series       | 11                            | 79             | 79                     |                   |
| Prabhu et al., 2017\textsuperscript{[24]} | 2B                | Retrospective comparative | 4                             | 452            | 186                    |                   |
| Tsuruta et al., 2014\textsuperscript{[25]} | 2B                | Retrospective comparative | 4.9                           | 21             | 24                     |                   |
| Total          |                   |                  | 135,743                       | 71,912         | 1282                   |                   |

### Table 2: Odds ratios and 95% confidence intervals for seven reported outcomes

| Outcomes       | Laparoscopic versus open | Robot versus open | Robot versus laparoscopic |
|----------------|--------------------------|-------------------|--------------------------|
| Infection      | 0.44 (0.29-0.66)         | 0.30 (0.08-0.81)  | 0.68 (0.19-1.80)         |
| Enterotomy     | 1.01 (0.39-3.78)         | 0.19 (0.01-1.22)  | 0.18 (0.01-1.03)         |
| Ileus          | 1.76 (0.87-4.16)         | 1.17 (0.45-3.47)  | 0.66 (0.31-1.44)         |
| Mortality      | 0.76 (0.29-2.50)         | 0.80 (0.03-5.90)  | 1.03 (0.04-6.90)         |
| Recurrence     | 0.98 (0.59-1.40)         | 0.32 (0.07-0.93)  | 0.33 (0.09-0.91)         |
| Seroma/haematoma | 1.28 (0.56-3.28)       | 0.50 (0.08-2.84)  | 0.39 (0.05-2.39)         |
| Urinary        | 0.97 (0.51-1.89)         | 0.93 (0.34-2.29)  | 0.96 (0.39-2.10)         |
disposables. A cost analysis obtained from publications on 20 different robotic procedures found that there was an average additional variable cost of $1600.²⁴

Several limitations exist in the current study. Most of the publications included in our network meta-analysis are retrospective studies and carry the limitation inherent in this design. There is also certainly some selection bias secondary to the preferential utilisation of one technique over the others based on factors such as the availability of laparoscopic and robotic technologies, patient body mass index, hernia size and elective versus emergent settings. Other limitations include the smaller sample size and shorter mean study duration of the robotic arm as compared to the laparoscopic and open arms. The mean duration of all studies included in our meta-analysis is 4.8 years; however, when divided into the three arms, the shortest mean duration of studies was from the robotic-assisted VHR arm at 3.5 years.

CONCLUSION

This study adds to a growing body of literature regarding the outcomes and advantages of robotic VHR. Although there are several limitations to this study, the decrease in hernia recurrence among the robotic repair arm warrants further investigation and research. Larger prospective and randomised clinical trials are needed.

Table 3: Reported post-operative complications

| Complication          | Studies | Cases (incidence) |
|-----------------------|---------|-------------------|
| Ileus                 | Open    | [3,7,8,15,16,21]  | 18 (0.018) |
|                       | Laparoscopic | [3,7,8,11,12,16,19-21] | 2729 (0.080) |
|                       | Robotic  | [9,10‑12,15]     | 32 (0.031)  |
| Enterotomy            | Open    | [7,8,17,21]      | 136 (0.014) |
|                       | Laparoscopic | [7,8,12,17,20,21] | 64 (0.012)  |
|                       | Robotic  | [9,12]           | 0.004       |
| Infection             | Open    | [2,4,8,15,17,21,23] | 4833 (0.136) |
|                       | Laparoscopic | [1,2,4,8,11,16,17,19-23] | 6611 (0.099) |
|                       | Robotic  | [1,9‑11,15]      | 9 (0.010)   |
| Mortality             | Open    | [4,5,7,15,17]    | 364 (0.003) |
|                       | Laparoscopic | [4,5,7,11,12,17] | 105 (0.002) |
|                       | Robotic  | [11,12,15]       | 1 (0.002)   |
| Recurrence            | Open    | [2,3,7,8,13,16,21-23] | 120 (0.105) |
|                       | Laparoscopic | [1,3,7,8,12,13,16,18,19,21,22] | 154 (0.073) |
|                       | Robotic  | [1,10,14,12]     | 6 (0.011)   |
| Seroma/haematoma       | Open    | [2,3,7,16,15,22] | 69 (0.067)  |
|                       | Laparoscopic | [2,3,7,16,22,23] | 87 (0.075)  |
|                       | Robotic  | [10,14,15]       | 4 (0.018)   |
| Urinary               | Open    | [4,7,8,15,16,22] | 779 (0.008) |
|                       | Laparoscopic | [1,4,7,8,11,12,16,19,22] | 1347 (0.022) |
|                       | Robotic  | [1,9,11,12,14,15] | 22 (0.021)  |

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Conflicts of interest
There are no conflicts of interest.

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