SUBMITTED 22 JAN 23
REVISION REQ. 20 MAR 23; REVISION RECD. 2 APR 23
ACCEPTED 16 MAY 23
ONLINE-FIRST: JULY 2023
DOI: https://doi.org/10.18295/squmj.7.2023.043

Robotic Appendicectomy

A review of feasibility

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Abstract
Acute appendicitis is one of the most common abdominal emergencies. There has been an increasing trend in the use of robotic surgery in abdominal surgery. However, it remains underutilised in emergency surgeries. We aimed to systematically review robotic appendicectomies (RA) feasibility. A 20-year systematic review was performed in compliance with PRISMA guidelines. MERSQI score was applied for quality assessment. The research protocol was registered with PROSPERO. The search resulted in 1242 citations, of which 9 articles were included. Quality scores mean:10.72(SD=2.56). The endpoints across the studies were: rate of conversion to open surgery, length of hospital stay, blood loss and operative time. RA is safe and feasible technique in elective and emergency settings with minimal blood loss. The operating time and the hospital stay were within acceptable limits. The major drawback of robotic surgery is its high cost and limited availability. Future studies are recommended to evaluate RA with a focus on its application during emergency and on its cost-effectiveness.
Keywords: Robot Surgery; Robotic-Assisted Surgery; Robot Enhanced Surgery; Robotic Surgical Procedure; Appendectomy; Appendicectomy; Robotic Appendicectomy; Gastrointestinal Surgical Procedure.

Introduction

Acute appendicitis is known to be the most common abdominal surgical emergency in the world, with around 50,000 acute appendicectomies performed annually in the UK.[1] Laparoscopic appendicectomy (LA) is considered the gold-standard management and is recommended over open appendectomy in all patient groups.[2,3] However, the COVID-19 pandemic brought a new challenge for surgeons undertaking laparoscopic procedures, with its safety being debated out of fear of contaminated aerosol transmission to healthcare workers.[4,5]

Over the last decade, there has been an increasing trend in the routine use of robotic surgery in several surgical specialties and nearly all surgical subspecialties have adopted it.[6,7] The use of the robotic system is known to improve precision, visualisation, spatial flexibility, and stability, compared with traditional laparoscopic techniques.[8,9] In particular, robotic surgery has shown to reduce the risk of potential viral transmission to the surgeons and theatre staff as it allows them to be remote from the patient and each other.[4,10,11] Although routinely used in elective cases, robotic surgery remains generally unexplored and potentially underutilised in emergency surgeries.[9,12,13]

This study aimed to systematically review robotic appendicectomy (RA) procedures in elective and emergency settings and study its indications and feasibility.

Methods

This study was registered with PROSPERO register for systematic reviews. The systematic review was performed in compliance with the PRISMA guidelines.[14]

Search strategy

A 20-year literature search using the search terms'' robotic appendectomy'' and ''robotic appendicectomy'' was carried out on PubMed, ScienceDirect and Cochrane databases for articles published from 2002 to April 2022 [Figure 1]. Mesh terms were used and did not reveal any new relevant citations.

Inclusion and exclusion criteria

All citations directly related to robotic appendicectomy were included in this study. Conference abstracts, letters to editors and non-English publications were excluded.

Procedure

The procedure comprised of two authors for citations inspection, which were systematically reviewed against the inclusion and exclusion criteria. The final list of citations was completed in consensus between the two authors. The search items were studied from the nature of the article, the date of publication, the aims and findings of the studies in relation to the robotic appendicectomy procedures and the type of robotic system used. In case the type of robotic system was not clearly mentioned in the manuscripts, corresponding authors were contacted for confirmation of the included type of robotic surgery. In only one study, the type of the used robotic system was not clearly mentioned, and authors were not reachable.

Quality assessment and synthesis

The retrieved citations were read for further assessment for eligibility. Our method for identifying and evaluating data complied with the PRISMA checklist and has been reported in line with assessing the methodological quality of systematic reviews (AMSTAR 2).[15] There was a good compliance with Amstar 2 tool. Reporting ‘’Yes’’ in 11 criteria and ‘’partial yes’’ in two. The ‘’no’’ were related to meta-analysis, which was not applicable in this study.

The Medical Education Research Study Quality Instrument (MERSQI) was used for quality assessments of studies.[16] This score contains 10 items that reflect 6 domains of study quality including study design, sampling, type of data, validity, level of data analysis, and outcomes. The score represented the mean of two independent assessors' quality estimations of each citation. MERSQI's maximum score was 18 with a potential range from 5 to 18. The maximum score for each domain was 3. The mean quality score was calculated to be 10.72 (SD= 2.56) = Moderate quality score of citation ~ 11. High quality score was ≥13 and Low-quality score was 5-9.

Risk of bias within and across studies

The risk of bias was assessed in a blind manner; and we calculated the mean score between two raters if the scores did not match. We also controlled for accumulated risk of bias by grading the body of evidence of the findings according to MERSQI score.

Results

Citation selection and characteristics

This 20-year systematic search resulted in 1346 citations. After scanning the titles and abstracts, relevant citations were extracted (Fig. 1). The inclusion and exclusion criteria were applied, duplicated and irrelevant citations were excluded. A final list of 9 citations was suitable to the research rationale. The full texts of the articles were read by two authors for further evaluation. The tabular analysis of the citations for RA procedures is presented in Table 1, which comprises details about studies such as the published journals, aims and findings of the studies, robotic system, quality scores and evidence grades of the studies.[17 to 25]

Risk of bias within and across studies

We applied MERSQI scores in our systematic review as it has been demonstrated to be a reliable and valid instrument for measuring methodological quality in research.[16] In addition, to decrease the risk of bias within studies in our systematic review, we excluded recommendations, letters to editors, abstracts and commentaries. The full texts of the retrieved citations were read for further assessment for eligibility. There was risk of bias within studies, which consisted of the small number of papers that studied RA procedures; however, there was a good number of RA procedures included in the included cohort studies.

Results of quality and evidence-grade assessments

For the included citations, the mean quality score was calculated to be 10.72 (SD= 2.56) and the scores ranged from 6.5 to 13.5, with 4 high quality, 2 moderate and 3 low quality studies.

Results of individual studies

A total of 174 procedures were included in this review, 161 elective, 12 emergency and one interval RA. Four citations reached high quality through MERSQI scores. Only one study did not specify the exact number of the included RA procedures.

Akl et al.'s retrospective analysis of 107 patients underwent elective RA in conjunction with other robotic gynaecological procedures between 2004 and 2007 was performed. The main objective was to evaluate the feasibility and safety of RA. The patients had a postoperative follow-up period of at least six weeks. The researchers encountered no perioperative complications related to concomitant during gynaecological procedures with no conversion required in any of the procedures. Additionally, the researchers found that RA could be performed effectively without significantly affecting the operative time.

Bütter et al.'s study aimed to measure the outcome of the first paediatric da Vinci surgery programme in Canada among 41 children. All the procedures were completed without the need for conversion to open or laparoscopic surgery. The researchers found that the use of the robotic system offered them a significant advantage compared to laparoscopic surgery. These included: markedly enhanced magnification and 3D visualisation, increased instrument dexterity and improved precision and ease of suturing.

Hüttenbrink et al.'s study aimed to investigate the safety and benefit for 53 patients undergoing incidental RA during robotic-assisted laparoscopic radical prostatectomy (RALRP) between 2012 and 2014. The findings supported the consideration of the coincidental RA as no intraoperative or postoperative complications were encountered. In addition, the median hospital stay was 5 days, which was similar when compared to other RALRP procedures during the same period.

Quilici et al.'s citation included a cohort study of 34,984 patients in which the value, cost and fiscal impact of robotic procedures for abdominal surgeries were compared to open and laparoscopic counterparts. The cost of RA was significantly higher compared to the laparoscopic technique with an average total cost per case of $13,210 versus $7709 for LA, respectively. In addition, the mean duration of robotic surgery was longer when compared to laparoscopic technique in abdominal surgery. However, this study contained few RA procedures, which made it difficult to obtain a valid comparison between the different surgical approaches. Furthermore, the use of robotic technology for abdominal surgical procedures provided no significant difference in clinical outcomes versus the other surgical techniques.

Synthesis of the studies

There was difference in the endpoints across the studies. These included: rate of conversion to open surgery, length of postoperative hospital stays, intraoperative blood loss and operative time. The length of hospital stay mean was 5.2 and estimated blood loss 22.5 ml.

Conversion rate and intra-operative complications

Akl et al. evaluated the safety and feasibility of elective RA during gynecologic robotic surgery.[17] In this study of 107 patients, none required conversion to laparoscopic or open surgery. Another study by Hüttenbrink et al. reported on 53 patients who underwent elective RA during robotic-assisted laparoscopic prostatectomy (RALRP).[22] The researchers reported no intraoperative or postoperative complications related to incidental RA and encouraged its consideration for patients scheduled for robotic-assisted prostate surgery.

Length of stay

Kelkar et al. aimed to analyse the safety and effectiveness of the Versius surgical system in its first-in-human use of 30 patients undergoing gynaecological or general surgical procedures.[24] Four patients with acute appendicitis underwent emergency RA with an average length of hospital stay of 4 days (2-7 days).

Yao et al. evaluated the feasibility and safety of the surgical robot, Micro Hand S. Between a total of 81 cases of robotic surgery, 3 patients had emergency RA for acute appendicitis with an average postoperative hospital stay of 6.3 days. [23]

Hüttenbrink et al. reported an average postoperative hospital stay of 5 days for elective RA during RALRP vs 6 days for all other RALRP performed in the same period of time.[22]

Estimated Blood loss

Kelkar et al.reported that the estimated blood loss was negligible (<5ml) in all four patients who had an emergency RA for acute appendicitis.[24] Yao et al. reported an intraoperative blood loss of 40.0 ml amongst the 3 patients who had emergency RA. [23]

Operative time

Kelkar et al. reported a median operative time of 105 min (80-135 min) amongst the four emergency RA with Yao et al. reporting a similar operative time of 130.0 min between the emergency RA cases.[23, 24]

Akl et al. reported an average time of 3.4 min (range 2-6) for RA after measuring the operative time of 10 consecutive robotic cases.[17] The authors concluded that RA can be performed effectively without any significant difference in the operative time.

On the other hand, Quillici et al. concluded that the mean duration of robotic surgery was significantly longer when compared to laparoscopic surgery; however, there were too few RA to obtain a valid comparison between the different surgical approaches. [25]

Discussion

To our knowledge, this is the first review to study robotic appendicectomy procedures. Our study showed that RA can be considered as a feasible and safe technique, mainly in elective settings. Indications of RA were acute and chronic appendicitis, mucocele resection, as well as being performed in conjunction with other robotic gynaecological and urological procedures.

Laparoscopic appendicectomy remains the gold standard for the management of appendicitis, due to its benefits such as the lower incidence of wound infections, less postoperative pain and shorter hospital stay in comparison to open appendicectomy.[26] Whilst the available literature on the use of robotic surgery in appendicectomy is somewhat limited, surgeons have reported more dexterity, greater precision, better visualisation and improved range of motion with its utilisation in abdominal surgery.[8, 9, 27] These major features have led to its widespread adoption in difficult operative access and technically challenging procedures.[28]

Particularly in light of the Covid-19 pandemic, surgeons considered robotic surgery as a safe alternative to clear the backlog of operations whilst reducing the risk of potential viral transmission. The offered advantages of robotic surgery include operating with lower pneumoperitoneum pressures, reducing the length of hospital stay and minimising contact between the patient and healthcare workers during surgery after trocars placement.[11, 29, 30]

Despite the advantages, drawbacks of robotic surgery still include limited availability and additional specialised surgical robotic training. In addition, the increased cost of robotic surgery remains one of its main limitations when compared to laparoscopic or open surgery. The robotic surgery requires specialised training and its cost of acquiring, operating and maintaining a surgical robotic system is significantly more expensive when compared to other surgical techniques.[25, 31, 32]

Our study included three robotic systems: the da Vinci robot, the Versius and the Micro Hand S. The da Vinci robot launched in 1999 and has remained the predominant robotic surgical system for over 20 years. However, with a cost of £1.7 million per robot, £1,000 per patient for disposables and £140,000 maintenance fees per year, newer cost-effective systems have emerged to improve on the da Vinci.[33, 34] The novel Micro Hand S has demonstrated significantly lower hospitalisation and operative costs in comparison to the da Vinci robotic system, ($p < 0.05$). The surgical instruments of the Micro Hand S have unlimited use whereas the instruments of the da Vinci surgical robot have a 10-use limit. Furthermore, the surgical instruments of the Micro hand S robot cost about 1,000 yuan per set which is roughly equivalent to £119 vs 2,000 yuan per set for the da Vinci, which is roughly equivalent to £239.[35, 36] The Versius surgical system is the first UK built surgical robot and is said to be the next major rival to the da Vinci. Although reports are limited about specific costs of the novel system, the Versius robot offers the advantages of being smaller, more versatile and more portable, improving its cost-effectiveness.[34]

The main limitation of this review was the limited number of citations that studied RA and the absence of randomised trials during this 20-year period. However, there was a good number of procedures in the cohort studies included in this review. Future research is needed to further evaluate the strengths and weaknesses of each robotic surgical system in appendicectomy, with a particular focus on its application during emergency settings and on its cost-effectiveness.

Conclusion

The present review included studies revealing robotic appendicectomy as a safe and feasible technique. RA could be performed effectively without the need for conversion and minimal blood loss. The operating time and the hospital stay were within acceptable limits. However, the major drawback of robotic surgery is its high cost. Future studies are recommended to further evaluate the different robotic surgical systems in appendicectomies, with a focus on its application during emergency procedures and on its cost-effectiveness.

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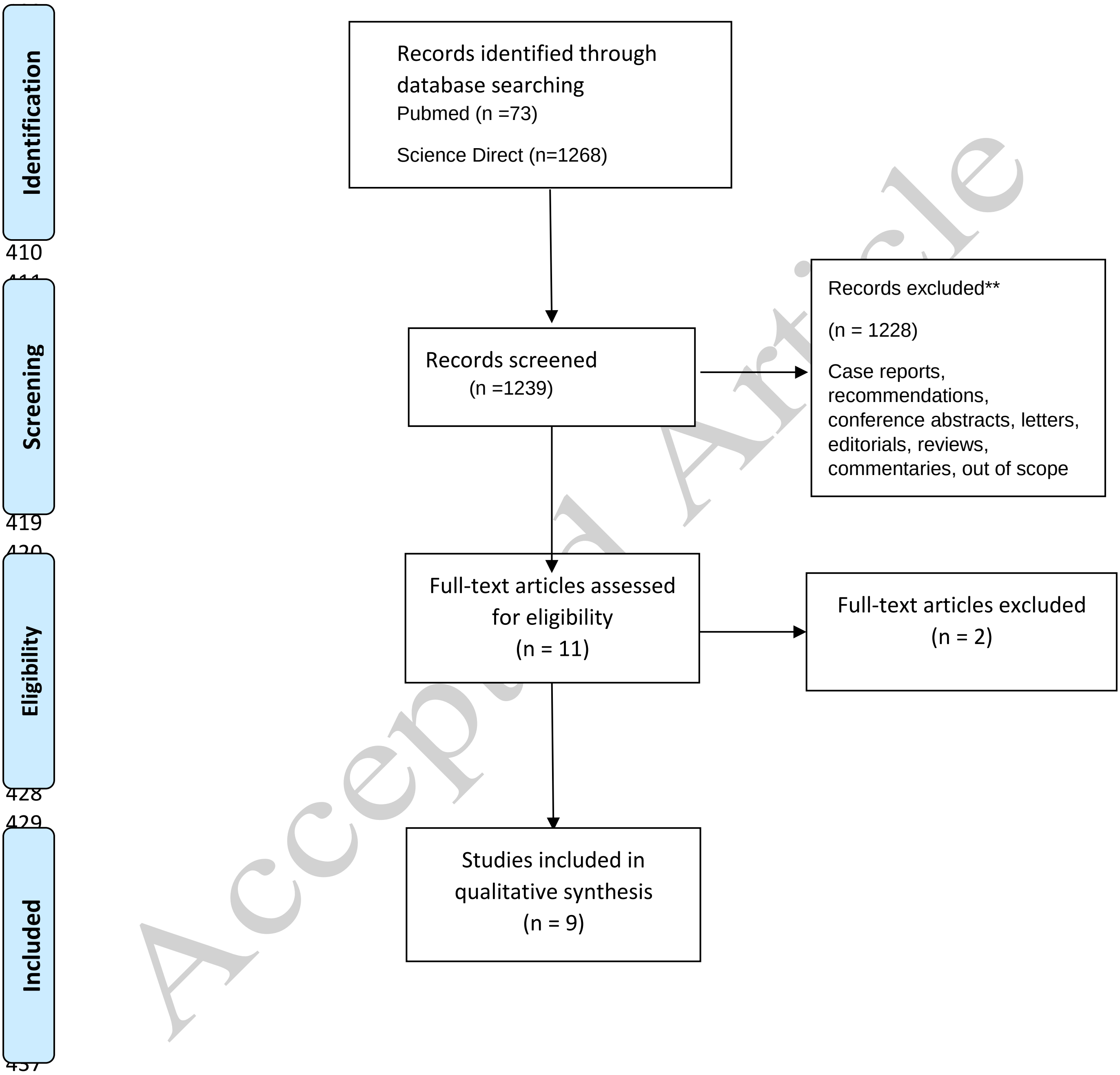

Figure 1: Flow diagram of the systematic search

Table 1: Tabular analysis of included citations

Author (year)	Journal	Type of study	Objective	Patients (n)	Indications	Robotic system	Findings/outcomes	MERSQI scores* (quality)
Akl et al. (2008)	The International Journal of Medical Robotics and Computer Assisted Surgery	Cohort study	To assess the feasibility, safety and pathological findings of incidental RA in patients undergoing robotic gynecological surgery.	Altogether Elective RA 107 patients.	Chronic pelvic pain and gynecological malignancies.	Da Vinci robotic system	Incidental RA was performed safely and effectively in conjunction with other robotic gynecological procedures with no perioperative complications related to appendicectomy.	13 (high)
Yi et al. (2015)	Surgical Endoscopy	Case series	To assess the safety and feasibility of the chinese minimally invasive surgical robot system "Micro Hand S" in its first clinical use	Altogether 3 patients (Emergency RA=2)	Acute appendicitis	Micro Hand S robotic surgery	The robot system "Micro Hand S" was safe and effective with no intraoperative complications or technical problems being encountered with its use. At three-month follow up, patients had no adverse reactions.	8 (low)
Yi et al. (2016)	Surgical Endoscopy	Case report	To develop and validate one low-cost and easy-use minimally invasive surgical robot system "Micro Hand S" that surgeons can use to resolve the complicated surgeries challenge.	Altogether 10 patients (Emergency RA=3)	Acute appendicitis	Micro Hand S robotic surgery	No intraoperative complications or technical problems were encountered with the use of the domestic produced "Micro Hand S" All patients recovered and were discharged from hospital without complications.	8 (low)
Bütter et al. (2016)	Journal of Robotic Surgery	Cohort study	To present the results of the first pediatric robotic surgery program in Canada.	Altogether 41 children Interval RA=1	Interval appendicectomy.	Da Vinci robotic system	All robotic procedures were completed without conversion, with no technical failures due to the robotic system.	13 (high)
Orcutt et al. (2017)	International journal of surgery	Case series	To present cases with appendiceal mucoceles that	Altogether 2 patients	Mucocele of appendix	Unclear	The robotic approach allowed meticulous dissection and	6.5 (low)

	case reports		were successfully treated with minimally invasive approaches.	Elective RA=1			intact removal of appendiceal mucocele with no intra or postoperative complications.	
Hüttenbrink et al. (2017)	Langenbeck's Archives of Surgery	Cohort study	To investigate the safety and patients benefit of incidental appendicectomy during RALRP.	Altogether 53 patients Elective RA=53 Histopathology: inconspicuous=33, postinflammatory changes=11, chronic appendicitis=4, appendicitis=3 and neoplasia=2	RALRP with incidental appendicectomy.	Da Vinci robotic system	Incidental appendicectomy during RALRP is a feasible and safe procedure and could be considered for patients scheduled for robot-assisted prostate surgery.	13.5 (high)
Yao et al. (2020)	International Journal of Surgery	Cohort study	To evaluate the feasibility and safety of the Micro Hand S surgical robot in general surgery.	Altogether 81 patients (Emergency RA=3)	Acute appendicitis	Micro Hand S robotic surgery	RA was successfully performed in all 3 patients. The operation time(min) 130.0, blood loss (ml) 40.0 and hospital stay (day) 6.3	11 (moderate)
Kelkar et al. (2020)	Surgical Endoscopy	Cohort study	To provide an initial safety analysis of the first 30 surgical procedures performed using the Versisus Surgical System.	Altogether 30 patients (Emergency RA=4)	Acute appendicitis	Versius Surgical System	RA was successfully carried out in all 4 patients. The operation time ranged between 80-135 minutes and estimated intraoperative blood loss was negligible.	10 (moderate)
Quilici et al. (2021)	Surgical Endoscopy	Cohort study	To define the value, cost, and fiscal impact of robotic-assisted procedures in abdominal surgery and	Altogether 34,984 patients (few unspecified number RA)	Abdominal surgery including AA.	Da Vinci surgical system	RA were performed at a higher cost vs laparoscopic appendicectomy, with an average total cost per case $13,210 vs $7709.	13.5 (high)

			provide clinical guidance for its routine use.				Robotic technology for gastrointestinal procedures is significantly more expensive than other surgical techniques.	

RA = robotic appendicectomy; AA = acute appendicitis; RALRP = robot-assisted radical prostatectomy.

*MERSQI

- Low quality 5-9
- Moderate quality 10-12
- High quality ≥13