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Evidence Review:

Robotic assisted surgery for oesophago-gastric cancers

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Contents

1. Introduction

Oesophago-gastric cancer is usually treated with surgery (either a gastrectomy or oesophagectomy), chemotherapy or radiotherapy and sometimes a combination of all three. Treatment will depend on the type of cancer, how far it has spread and the general health of the patient. For cancers where surgery is deemed appropriate, the approach to surgery is determined by the position of the tumour not only to ensure radical resection but also safe reconstruction. Robotic assisted surgery is seen by some as a progression on the existing techniques using a sophisticated, computer-enhanced system to guide the surgical tools.

2. Summary of results

The clinical evidence review aimed to address the following research questions:

Question 1: What evidence is available on the clinical effectiveness of robot-assisted surgery for the treatment of oesophago-gastric cancer compared to existing surgical techniques?
Question 2: What evidence is available on the cost effectiveness of robot-assisted surgery for the treatment of oesophago-gastric cancer compared to existing surgical techniques?
Question 3: What is the learning curve for robotic-assisted surgery for oesophago-gastric cancer?

Summary:

The literature search returned 298 abstracts from which 25 studies were considered in detail. Most of the studies were specific to gastric cancer and conducted in South East Asia. There was reference to only two studies which included surgery for oesophageal cancer. In addition, in most of the Asian studies early gastric cancers were treated which is not directly applicable to experience in England. The data is from retrospective observational studies of variable quality. There were no randomised control trials. Many of the systematic reviews and meta analyses include the same group of studies (and thus patients).

Robotic surgery is being used as a minimally invasive modality for surgery because of its assumed technical superiority over conventional laparoscopy. There is, however, limited evidence of superiority in relation to oesophago-gastric cancer. Most of the studies directly comparing laparoscopic to robotically assisted surgery were of poor methodological quality and it is not possible to conclude whether robotic techniques are superior or even non-inferior to standard laparoscopic techniques. There is little to no robust survival data and thus it is equally not possible to state that there is a survival advantage. At best, the short-term operative outcomes are equivalent. There is a blood loss and length of stay advantage, but this is at the expense of longer operating time which is consistently reported in the studies considered.

Much of the literature reports on technical aspects and efficacy as opposed to outcomes. Studies mostly conclude that the robotic technique is feasible and outcomes are acceptable. Few studies reported survival. Some of the studies report short-term oncological outcomes that are equivalent when comparing robotic and laparoscopic surgery, but this cannot be stated as an evidence based conclusion, given the lack of comparative evidence. Similarly, whilst there may be advantages of robotically assisted surgery (compared to laparoscopic) with regards to blood loss and shorter length of stay (LOS), given the lack of comparative evidence it is difficult to state this as an evidence based conclusion. Finally, there are reported advantages to laparoscopic technique with regards to operation time (and thus theatre utilisation) but again there is little comparative data on which to draw this conclusion. There is some (inevitable) duplication in the studies included in the various systematic reviews. No formal cost effectiveness studies were found.

Question 1: What evidence is available on the clinical effectiveness of robot-assisted surgery for the treatment of oesophago-gastric cancer compared to existing surgical techniques?

Chuan (2015) conducted a meta analysis of available RCTs and observational data. It was reported that operation time was significantly longer; that blood loss was less; and length of stay was shorter in the robotic surgery group compared to those receiving laparoscopic surgery. Resection margin and postoperative complications were similar in both groups. These findings by Chuan et al., 2015 typifies most of the literature reviewed with the findings remarkably consistent across studies.

Xiong (2013) concluded in a meta analysis that robotic gastrectomy is a safe technique for treating gastric cancer

that compares favourably with laparoscopic gastrectomy in short term outcomes. However, the long term outcomes between the two techniques need to be further examined.

Xiong (2012) in a meta analysis found less blood loss and shorter length of stay for robotically assisted surgery. No significant differences reported on other outcomes.

Zong (2014) concluded that robotically assisted surgery is technically feasible. In keeping with other studies it has a longer operative time. There are some advantages regarding blood loss, but no significant difference between lymph node harvest, morbidity and mortality. Resection margin is not reported. This was a meta analysis of observational studies.

Coratti (2015) concluded, in a 98 patient case series, that robot-assisted gastrectomy for the treatment of gastric cancer is safe and feasible. It provides long-term outcomes comparable to most open and laparoscopic series.

Okumura (2015) concluded that there was no difference in outcomes comparing robotic gastrectomy in older patients compared to younger patients, and were comparable to the outcomes achieved in laparoscopic surgery in older patients.

Tokunaga (2015) reported that robotic gastrectomy was considered safe in terms of the incidence and severity of post operative outcomes.

Huang (2012) reported a case series of 689 patients undergoing gastrectomy (586 open, 64 laparoscopic and 39 robotic). Robotic gastrectomy was associated with less blood loss, shorter hospital stay, and longer operative time than open and laparoscopic gastrectomy. The retrieved lymph node numbers were similar between the open and robotic groups. Post-operative morbidity rates were similar among the three groups.

Shen (2015) reported on a case series of 423 patients undergoing robotic (n=93) or laparoscopic (n=330) gastrectomy for gastric cancer. The comparative study demonstrates that robotic assisted gastrectomy is as acceptable as laparoscopic gastrectomy in terms of surgical and oncologic outcomes, with lower estimated blood loss, acceptable complications, and radical resection. Robotic assisted gastrectomy is a promising approach for the treatment of gastric cancer although the indication of patients for robotic assisted gastrectomy is critical.

Hyun (2013) concluded that the short-term oncological outcomes of robotically assisted surgery were comparable with those of the other approaches and that laparoscopic gastrectomy was a shorter procedure and less expensive.

Given the state of the literature it is not possible to draw conclusions that robotically assisted oesophago-gastric cancer resection is more effective than the laparoscopic or open procedure technique.

Question 2: What evidence is available on the cost effectiveness of robot-assisted surgery for the treatment of oesophago-gastric cancer compared to existing surgical techniques?

No formal cost effectiveness studies were found.

Given the lack of data on long-term oncologic or survival outcomes, it is not readily possible to draw any conclusions that robotically assisted techniques offer significant advantage. It is also a more expensive approach.

Kim (2015) compared the short-term surgical outcomes including the financial cost of robotic and laparoscopic gastrectomy. This study concluded that whilst the use of robotic systems is assumed to provide a technically superior operative environment for minimally invasive surgery, this analysis of perioperative surgical outcomes indicated that robotic gastrectomy is not superior to laparoscopic gastrectomy, and is significantly more costly. Patients treated with robotic surgery showed significantly longer operative time (robotic = 221 minutes vs. laparoscopic = 178 minutes; $P < 0.001$) and significantly higher total costs (£8,814 vs. laparoscopic = £5,309; $P < 0.001$), compared with those who underwent laparoscopic gastrectomy. N.B. GBP values converted from USD on 18/11/15 at exchange rate of 0.656.

Park JY (2012) concluded in a small observational study that operative time was longer with robotic approaches and there was no difference in outcomes with respect to surgical stress. The cost of robotic surgery was higher than laparoscopic techniques.

Question 3: What is the learning curve for robotic-assisted surgery for oesophago-gastric cancer?

There was some literature reporting on training and learning curve issues, many of these were not considered in the final analysis for comparative effectiveness purposes as the studies were focused on learning curve, not outcome. Most commonly it is reported that the learning curve is shorter than for laparoscopic techniques. It is also commonly reported that skill acquisition is dependent on having prior laparoscopic skills.

Huang (2012) highlighted a significant learning curve effect in the initial 25 cases of robotic surgery with respect to operative time and retrieval of lymph nodes. Park (2013) analysed the learning curve of over 200 cases of robotic assisted gastrectomy. Park (2013) concluded that increased experience (comparing the first 100 with the second 100 cases) with the robotic procedure for gastric cancer was associated with improved outcomes, especially in operating time, lymph node retrieval and shortened hospital stay of complicated patients. Further development of surgical techniques and technology might enhance the role of robotic surgery for gastric cancer.

3. Research questions

• What evidence is available on the clinical effectiveness of robot-assisted surgery for the treatment of oesophago-gastric cancer compared to existing surgical techniques?
• What evidence is available on the cost effectiveness of robot-assisted surgery for the treatment of oesophago-gastric cancer compared to existing surgical techniques?
• What is the learning curve for robotic-assisted surgery for oesophago-gastric cancer?

4. Methodology

A review of published, peer reviewed literature has been undertaken based on the research questions set out in Section 3 and a search strategy agreed with the lead clinician and public health lead for this policy area. This has involved a PubMed search and search of the Cochrane database for systematic reviews, in addition to review of any existing NICE or SIGN guidance. The evidence review has been independently quality assured.

An audit trail has been maintained of papers excluded from the review on the basis of the inclusion and exclusion criteria agreed within the search strategy. The full list has been made available to the clinicians developing the policy where requested.

5. Results

A detailed breakdown of the evidence is included in the Appendix.

Appendix One

Level	Study design and intervention			Outcomes					Reference	Other		
Level of evidence	Study design	Study size	Intervention	Category	Primary Outcome	Primary Result	Secondary Outcome	Secondary Result	Reference	Complications noted	Benefits noted	Comments
3	Systematic + Meta Analysis	1796	Robotic assisted gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operation time	Operation time was significantly shorter in the laparoscopic surgery group (weighted mean difference 42.9; 95 % confidence interval 20.87 to 64.92 min; p < 0.05)	Blood loss, post operative stay, resection margin	Blood loss weighted mean difference was -16.07 (95% confidence interval -32.78 to 0.64 mL; p < 0.05) in favour of robotic surgery. Postoperative stay weighted mean difference was -1.98 (95% confidence interval -3.66 to -0.3 days; p < 0.05) in favour of the robotic surgery group. Resection margin, and postoperative complications were similar in both groups.	Chuan, Li; Yan, Shi; Pei-Wu, Yu. Meta-analysis of the short-term outcomes of robotic-assisted compared to laparoscopic gastrectomy. Minim Invasive Ther Allied Technol 2015;24(3):127-134.	NA	Shorter LOS, lower blood loss, similar removal margin.	Population: Age ranges in studies included from 53-63. No mean age given. Indication is gastric cancer. Summary comments: Well conduced systematic review and meta analysis. 5 studies included. Outcomes in favour of robotic surgery are blood loss and length of stay (LOS), outcomes in favour of laparoscopic are operation time (and thus theatre use). Advantage to laparoscopic for distal resection margin, no difference for proximal margin of resection. Survival not reported. No difference for complication rate.
3	Systematic + Meta Analysis	1875	Robotic assisted gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operative time	Longer operative time p=<0.05 in robotically assisted group	Blood loss, distal resection margin	Lower estimated blood loss and longer distal resection margin in the robotic group	Shen, Wei-Song; Xi, Hong-Qing; Chen, Lin; Wei, Bo. A meta-analysis of robotic versus laparoscopic gastrectomy for gastric cancer. Surg Endosc 2014;28(10):2795-2802.	NA	Complications, hospital stay, proximal margin, and harvested lymph nodes for robotic assisted gastrectomy (RAG) and laparoscopic assisted gastrectomy (LAG) were similar.	Population: Age information not given. Indication is gastric cancer. Summary comments: Well conducted systematic review and meta analysis. Robotically assisted surgery reported to have lower blood loss, advantage with regards to removal margin and similar complication rate, LOS, and proximal margin. No survival advantage reported. Robotically assisted has longer operative time.

3	Systematic + Meta Analysis	8493	Robotic assisted gastrectomy Comparator: Open gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Blood loss	Intraoperative blood loss and hospital stay were significantly reduced by robotic assisted surgery (weighted mean difference (WMD)=68.47 and 95% CI, 63.40−73.54; WMD=−106.63 and 95% CI, −163.13−−50.13; WMD=−2.49 and 95% CI, −3.72−1.27).	Operative time, lymph node harvest, morbidity and mortality and anastomotic leak.	The mean operation time of robotic assisted surgery was 68.47 minutes longer than open surgery. The difference of lymph node harvest between robotic assisted surgery and open surgery was not statistically significant (WMD=−0.78 and 95% CI, −2.15−0.59). Analyses on morbidity and mortality indicated that there was no significant differences between robotic assisted surgery and open surgery (OR=0.92 and 95% CI, 0.69−1.23; OR=0.72 and 95% CI, 0.25−2.06). Also, specifically for anastomotic leakage, no difference was observed between two groups (OR=1.72 and 95% CI, 0.97−3.07).	Zong, Liang; Seto, Yasuyuki; Aikou, Susumu; Takahashi, Takamasa. Efficacy evaluation of subtotal and total gastrectomies in robotic surgery for gastric cancer compared with that in open and laparoscopic resections: a meta-analysis. PLoS ONE 2014;9(7):e103312.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Study concluded that robotically assisted surgery is technically feasible. In keeping with other studies there was a longer operative time. Some advantages regarding blood loss & no significant difference between lymph node harvest, morbidity and mortality. Resection margin not reported. This was a meta analysis of observational studies.

3	Systematic + Meta Analysis	2495	Robotic assisted gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Blood loss	Robotic assisted gastrectomy is associated with lower blood loss.	Distal and proximal resection margin, lymph node harvest, rate of conversion to open surgery, morbidity, anastomotic leakage or stenosis	Robotic assisted gastrectomy was associated with a significantly longer operative time and shorter distal resection margin. In addition, there was no significant difference in the number of retrieved lymph nodes, proximal resection margin, rate of conversion to open surgery, overall morbidity, anastomotic leakage, anastomotic stenosis, intestinal obstruction, time to first flatus, length of hospital stay, and perioperative mortality rates between the two groups.	Xiong, Junjie; Nunes, Quentin M.; Tan, Chunlu; Ke, Nengwen; Chen, Yonghua; Hu, Weiming; Liu, Xubao; Mai, Gang. Comparison of short-term clinical outcomes between robotic and laparoscopic gastrectomy for gastric cancer: a meta-analysis of 2495 patients. J Laparoendosc Adv Surg Tech A 2013;23(12):965-976.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Study concludes that robotic assisted gastrectomy is comparable to laparoscopic gastrectomy with respect to safety, technical feasibility, and oncological effectiveness in the treatment of gastric cancer. Arguably this is an efficacy study, the study also concludes there is a need for a randomised control trial.

3	Systematic + Meta Analysis	7200	Robotic assisted gastrectomy Comparator: Laparoscopic and open gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operating times	Robotic assisted gastrectomy was associated with longer operating times than laparoscopic gastrectomy and open gastrectomy (weighted mean difference 61.99 and 65.73 min respectively; P ≤ 0.001)	Lymph node retrieval, resection margin length, blood loss, length of stay (LOS), post operative complications.	The number of retrieved lymph nodes and the resection margin length in robotic assisted gastrectomy were comparable with those of laparoscopic gastrectomy and open gastrectomy. Estimated blood loss is significantly less in robotic assisted gastrectomy than in open gastrectomy (P = 0.002), but not laparoscopic gastrectomy. Mean hospital stay for robotic assisted gastrectomy was similar to that for laparoscopic gastrectomy (P = 0.14). In contrast, hospital stay was significantly shorter, by a mean of 2.18 days, for robotic assisted gastrectomy compared with open gastrectomy (P < 0.001). Postoperative complications were similar for all three operative approaches.	Hyun, M. H.; Lee, C. H.; Kim, H. J.; Tong, Y.; Park, S. S.. Systematic review and meta-analysis of robotic surgery compared with conventional laparoscopic and open resections for gastric carcinoma. Br J Surg 2013;100(12):1566-1578.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Well conducted meta analysis of observational studies. Short term outcomes sometimes in favour of laparoscopic, sometimes in favour of robotic. No long term outcomes reported. Laparoscopic was a shorter procedure and less expensive than robotic assisted gastrectomy.

3	Systematic + Meta Analysis	1967	Robotic assisted gastrectomy Comparator: Laparoscopic and open gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Length of stay	Shorter hospital stay was noted with robotic gastrectomy than with open gastrectomy (weighted mean difference: -2.92, 95% confidence interval: -4.94 to -0.89, P=0.005).	Operative blood loss, operative time, lymph node retrieval and complication rates.	Significant reduction in intraoperative blood loss with robotic gastrectomy compared with laparoscopic gastrectomy (weighted mean difference: -35.53, 95% confidence interval: -66.98 to -4.09, P=0.03). Robotic gastrectomy associated with a longer operative time versus laparoscopic gastrectomy (weighted mean difference: 63.70, 95% confidence interval: 44.22 to 83.17, P<0.00001) and robotic gastrectomy versus open gastrectomy (weighted mean difference: 95.83, 95% confidence interval: 54.48 to 137.18, P<0.00001). Analysis of the number of lymph nodes retrieved and overall complication rates revealed that these outcomes did not differ significantly between the groups.	Marano, Alessandra; Choi, Yoon Young; Hyung, Woo Jin; Kim, Yoo Min; Kim, Jieun; Noh, Sung Hoon. Robotic versus Laparoscopic versus Open Gastrectomy: A Meta-Analysis. J Gastric Cancer 2013;13(3):136-148.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Systematic review and meta analysis comparing robotic vs. laparoscopic vs. open surgery. Non randomised studies. Robotic assisted surgery carries advantages regarding blood loss and length of stay (LOS) at a price of longer operative time. There are similar outcomes in other domains (including lymph node and complication rates) when compared to laparoscopic. Removal margin and survival not reported.
3	Systematic + Meta Analysis	2325	Robotic assisted gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operative time	Robotic gastrectomy was associated with longer operative time - weighted mean difference of 50 minutes.	Blood loss	Robotic gastrectomy was associated with less blood loss. There was no significant difference in terms of hospital stay, total postoperative complication rate, proximal margin, distal margin, numbers of harvested lymph nodes and mortality rate between robotic gastrectomy and laparoscopic gastrectomy.	Liao, Gui-Xiang; Xie, Guo-Zhu; Li, Rong; Zhao, Zhi-Hong; Sun, Quan-Quan; Du, Sha-Sha; Ren, Chen; Li, Guo-Xing; Deng, Hai-Jun; Yuan, Ya-Wei. Meta-analysis of outcomes compared between robotic and laparoscopic gastrectomy for gastric cancer. Asian Pac. J. Cancer Prev. 2013;14(8):4871-4875.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: 2,235 patients with gastric cancer of which 1,473 had undergone laparoscopic gastrectomy, and 762 had received robotic gastrectomy. Compared with laparoscopic gastrectomy, robotic gastrectomy was associated with longer operative time but less blood loss. There was no significant difference in terms of hospital stay, total postoperative complication rate, proximal margin, distal margin, numbers of harvested lymph nodes and mortality rate between robotic gastrectomy and laparoscopic gastrectomy.

3	Systematic + Meta Analysis	5780	Robotic assisted gastrectomy Comparator: Open gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operation time	Robotic gastrectomy has a significantly longer operation time (weighted mean differences (WMD) =92.37	Blood loss, hospital length of stay (LOS), complication rates, wound healing, harvested lymph nodes, operative mortality.	Lower blood loss (WMD: -126.08, 95% CI: -189.02 to -63.13, P<0.0001), and shorter hospital stay (WMD = -2.87; 95% CI: -4.17 to -1.56; P<0.0001). No statistical difference was noted based on the rate of overall postoperative complication, wound infection, bleeding, number of harvested lymph nodes, anastomotic leakage and postoperative mortality rate.	Liao, Guixiang; Chen, Jiarong; Ren, Chen; Li, Rong; Du, Shasha; Xie, Guozhu; Deng, Haijun; Yang, Kaijun; Yuan, Yawei. Robotic versus open gastrectomy for gastric cancer: a meta-analysis. PLoS ONE 2013;8(12):e81946.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Meta analysis of observational studies comparing open vs robotic. Robotic surgery has longer operation time, with lower blood loss and shorter LOS. There were no differences reported in other outcomes.
3	Systematic + Meta Analysis	918	Robotic assisted gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operation time	Robotic gastrectomy for gastric cancer was associated with a significantly longer operative time (WMD: 68.77min).	Blood loss, lymph node retrieval, operative mortality, length of stay.	Significantly less intraoperative blood loss (WMD: -41.88, 95% CI: -71.62 to -12.14; P = 0.006). No significant differences were found in the number of lymph nodes (WMD: -0.71, 95% CI: -6.78 to 5.36; P = 0.82), overall morbidity (WMD: 0.74, 95% CI: 0.47 to 1.16; P = 0.19), perioperative mortality rates (WMD: 1.80, 95% CI: 0.30 to 10.89; P = 0.52) and length of hospital stay (WMD: 0.42, 95% CI: -1.87 to 0.79; P = 0.42)	Xiong, Binghong; Ma, Li; Zhang, Caiquan. Robotic versus laparoscopic gastrectomy for gastric cancer: a meta-analysis of short outcomes. Surg Oncol 2012;21(4):274-280.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Meta analysis of observational studies. Concludes lower blood loss, shorter length of stay - to the advantage of robotically assisted surgery. No significant differences reported on other outcomes.
3	Other	Not stated	Robotic assisted gastrectomy and oesophagectomy Comparator: Laparoscopic and open gastrectomy and oesophagectomy	Clinical effectiveness of the intervention	Operative outcomes and hospital stay	Improved operative outcomes and hospital stays were demonstrated with a reduction of 2 days when the robotic-assisted gastrectomy technique was employed compared with the open approach.	Short and long term oncologic outcomes	No improvement in oncological outcomes could be identified with the use of the robot for either oesophageal or gastric cancer resection.	Clark, James; Sodergren, M. H.; Purkayastha, S.; Mayer, E. K.; James, D.; Athanasiou, T.; Yang, G.-Z.; Darzi, A.. The role of robotic assisted laparoscopy for oesophagogastric oncological resection; an appraisal of the literature. Dis. Esophagus 2011;24(4):240-250.	NA	In terms of short-term oncological outcomes, these were at least equivalent to the open approach for oesophageal cancer and early stage gastric cancer.	Population: Age information not given. Indications are oesophageal and gastric cancer. Summary comments: Systematic review of level 3 and 4 evidence. The need for robust RCTs was noted. Short term outcomes were considered equivalent to laparoscopic surgery.
3	Systematic	199	Robotic assisted gastrectomy Comparator: None	Clinical effectiveness of the intervention	Operation time	Mean operative times were 265 minutes and 334 minutes for total and sub-total gastrectomy respectively.	Blood loss, conversion to open procedure, lymph node retrieval, complication rate, operative mortality, length of stay (LOS).	Mean blood loss reported was 113 mL (range: 12-1400). Conversion rate was 2.5%. Average lymph nodes retrieval was 32 (range: 11-83). Twenty-nine complications were reported (14.6%). Mortality rate was 1.5%. Mean length of stay was 10 days (range: 3-175).	Buchs, N. C.; Bucher, P.; Pugin, F.; Morel, P.. Robot-assisted gastrectomy for cancer. Minerva Gastroenterol Dietol 2011;57(1):33-42.	NA	NA	Population: Average age - 63 years. Indication is gastric cancer. Summary comments: Meta analysis of observational data, with no comparison. Useful data on some of the key metrics. Not really able to draw any conclusions with respect to comparison to laparoscopic or open procedure.

3	Case series	698 (of which 39 were robotic assisted surgery technique)	Robotic assisted gastrectomy Comparator: Laparoscopic and open gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Blood loss, hospital stay, operative time	Robotic gastrectomy was associated less blood loss, shorter hospital stay, and longer operative time than open and laparoscopic gastrectomy	Retrieved lymph node, postoperative morbidity rates were similar among the three groups. In terms of the learning curve of robotic gastrectomy - operative time and docking time were significantly reduced in the recent robotic group (n=14) compared to the initial robotic group (n=25).	Retrieved lymph node numbers were similar between the open and robotic groups. Postoperative morbidity rates were similar among the three groups.	Huang, Kuo-Hung; Lan, Yuan-Tzu; Fang, Wen-Liang; Chen, Jen-Hao; Lo, Su-Shun; Hsieh, Mao-Chih; Li, Anna Fen-Yau; Chiou, Shih-Hwa; Wu, Chew-Wun. Initial experience of robotic gastrectomy and comparison with open and laparoscopic gastrectomy for gastric cancer. J. Gastrointest. Surg. 2012;16(7):1303-1310.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Large case series, including a relatively small number of robotic assisted cases. The open group was associated with a larger tumour size, more D2 dissection, more advanced tumour stage, and more blood loss than the groups treated with laparoscopic and robotic methods.
3	Case series	502	Robotic assisted gastrectomy Comparator: None	Clinical effectiveness of the intervention compared to existing interventions	Short term operative outcomes	Short-term operative outcomes including complications and pathological parameters were comparable between the two robotic groups.	Disease free survival and overall survival	Disease-specific survival to the younger robotic group although overall survival was worse	Okumura, Naoki; Son, Taeil; Kim, Yoo Min; Kim, Hyoung-Il; An, Ji Yeong; Noh, Sung Hoon; Hyung, Woo Jin. Robotic gastrectomy for elderly gastric cancer patients: comparisons with robotic gastrectomy in younger patients and laparoscopic gastrectomy in the elderly. Gastric Cancer 2015;0(0):0.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: This study concluded that there was no difference in outcomes comparing robotic gastrectomy in older patients compared to younger patients, and were comparable to the outcomes achieved in laparoscopic surgery in older patients. This was a study in a single, high volume centre.

3	Case series	120	Robotic assisted gastrectomy Comparator: None	Clinical effectiveness of the intervention	Postoperative intra-abdominal infectious complications, including anastomotic leakage, pancreas-related infection, and intra-abdominal abscess	The incidence of intra-abdominal infectious complications was 3.3% (95 % CI 0.9-8.3 %), and all complications were successfully treated conservatively without re-operation. The incidence of overall adverse events was 14.2% (95 % CI 8.5-21.7 %).	Overall survival, relapse-free survival, RG completion rate, and incidence of all surgical morbidities	Three patients required conversion to open gastrectomy according to the protocol due to advancement of disease.	Tokunaga, Masanori; Makuuchi, Rie; Miki, Yuiciro; Tanizawa, Yutaka; Bando, Etsuro; Kawamura, Taiichi; Terashima, Masanori. Late phase II study of robot-assisted gastrectomy with nodal dissection for clinical stage I gastric cancer. Surg Endosc 2015;0(0):0.	NA	NA	Population: Age information not given. Indication is stage I gastric cancer. Summary comments: Study reports that robotically assisted surgery is safe.
3	Case series	98	Robotic assisted gastrectomy Comparator: None	Clinical effectiveness of the intervention	Postoperative morbidity and mortality	Postoperative morbidity and mortality were 12.2% (distal) and 4.1% (total) respectively.	Cumulative 5 year overall survival	Cumulative 5 year overall survival (OS) was 73.3% (95% CI: 62.2-84).	Coratti, A.; Fernandes, E.; Lombardi, A.; Di Marino, M.; Annecchiarico, M.; Felicioni, L.; Giulianotti, P. C.. Robot-assisted surgery for gastric carcinoma: Five years follow-up and beyond: A single western center experience and long-term oncological outcomes. Eur J Surg Oncol 2015;41(8):1106-1113.	NA	Open conversion occurred in seven patients (7.1%).	Population: Age information not given. Indication is gastric cancer. Summary comments: This study reports on the five year outcomes from a single centre. It provides some useful intelligence on overall survival at five years.

3	Case series	423	Robotic assisted gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operative time, blood loss, harvested lymph nodes	Robotic assisted gastrectomy was associated with a longer operative time (P < 0.001), lower blood loss (P = 0.001), and more harvested lymph nodes (P = 0.047).	Complications and resection margins.	The robotic assisted gastrectomy group had postoperative complications of 9.8%, comparable with those of the laparoscopic gastrectomy group (P = 0.927). Only three patients in the laparoscopic gastrectomy group had positive margins, and the R0 resection rate for robotic assisted gastrectomy and laparoscopic gastrectomy was similar (P = 0.823).	Shen, Weisong; Xi, Hongqing; Wei, Bo; Cui, Jianxin; Bian, Shibo; Zhang, Kecheng; Wang, Ning; Huang, Xiaohui; Chen, Lin. Robotic versus laparoscopic gastrectomy for gastric cancer: comparison of short-term surgical outcomes. Surg Endosc 2015;0(0):0.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Relatively large case series. Confirms the general nature of the evidence for robotic assisted gastrectomy i.e. it is associated with longer operative time, lower blood loss, shorter length of stay (LOS). There was similar R0 resection rate comparing a cohort receiving robotically assisted vs laparoscopic surgery.
3	Case series	770 (robotic n=148, laparoscopic n=622)	Robotic assisted gastrectomy Comparator: None	Clinical effectiveness of the intervention	Surgical outcomes (not specified)	The surgical outcomes following distal gastrectomy were similar between the robotic and laparoscopic groups regardless of the obesity status	Lymph node retrieval	The number of total and N2-area lymph nodes were significantly higher in the robotic group than in the laparoscopic group in non-obese patients with VFA < 100 cm(2) (total, 38.8 vs. 46.5; p = 0.018; N2 area, 9.0 vs. 12.4; p = 0.041), but no significant differences were observed in obese population.	Park, Ji Yeon; Ryu, Keun Won; Reim, Daniel; Eom, Bang Wool; Yoon, Hong Man; Rho, Ji Yoon; Choi, Il Ju; Kim, Young-Woo. Robot-assisted gastrectomy for early gastric cancer: is it beneficial in viscerally obese patients compared to laparoscopic gastrectomy?. World J Surg 2015;39(7):1789-1797.	Robotic group developed less severe complications after total gastrectomy compared to laparoscopic group in non-obese patients.	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Park concluded that in a cohort of obese patients, robotic assistance did not improve surgical outcomes over the laparoscopic approach for those undergoing distal gastrectomy.

3	Case series	108	Robotic assisted esophagectomy Comparator: None	Clinical effectiveness of the intervention	Duration of procedure	Mean duration 381 minutes (range 264-636 minutes)	Lymph node removal and disease free / overall survival	The median number of lymph nodes was 26, median follow-up was 58 months, 5 year overall survival was 42%, median disease-free survival was 21 months, and median overall survival was 29 months.	van der Sluis, P. C.; Ruurda, J. P.; Verhage, R. J. J.; van der Horst, S.; Haverkamp, L.; Siersema, P. D.; Borel Rinkes, I. H. M.; Ten Kate, F. J. W.; van Hillegersberg, R.. Oncologic Long-Term Results of Robot-Assisted Minimally Invasive Thoraco-Laparoscopic Esophagectomy with Two-Field Lymphadenectomy for Esophageal Cancer. Ann. Surg. Oncol. 2015;0(0):0.	NA	NA	Population: Age information not given. Indication is oesophageal cancer. Summary comments: Single centre study. Provides some useful data on short and medium term outcomes. Non-comparative.
3	Other	434 (robotic n=223, laparoscopic n=211)	Robotic assisted gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Surgical complication rates	Both groups showed similar overall complication rates (robotic = 11.9% vs laparoscopic = 10.3%) and major complication rates (robotic = 1.1% vs laparoscopic = 1.1%) with no operative mortality in either group.	Operative time and cost	Patients treated with robotic surgery showed significantly longer operative time (robotic = 221 minutes vs laparoscopic = 178 minutes; P < 0.001) and significantly higher total costs (robotic = £8,814 vs. laparoscopic = £5,309; P < 0.001), compared with those who underwent laparoscopic gastrectomy. N.B. GBP values converted from USD on 18/11/15 at exchange rate of 0.656	Kim, Hyoung-Il; Han, Sang-Uk; Yang, Han-Kwang; Kim, Young-Woo; Lee, Hyuk-Joon; Ryu, Keun Won; Park, Joong-Min; An, Ji Yeong; Kim, Min-Chan; Park, Sungsoo; Song, Kyo Young; Oh, Sung Jin; Kong, Seong-Ho; Suh, Byoung Jo; Yang, Dae Hyun; Ha, Tae Kyung; Kim, Youn Nam; Hyung, Woo Jin. Multicenter Prospective Comparative Study of Robotic Versus Laparoscopic Gastrectomy for Gastric Adenocarcinoma. Ann. Surg. 2015;0(0):0.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: This study concluded that whilst the use of robotic systems is assumed to provide a technically superior operative environment for minimally invasive surgery - this analysis of perioperative surgical outcomes indicated that robotic gastrectomy is not superior to laparoscopic gastrectomy, and significantly more costly.

3	Other	109 (robotic n=51, laparoscopic n=58)	Robotic assisted gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operative time	Operation time of robotic group was longer than laparoscopic group (p < 0.001),	Post operative complications, disease free and overall survival	Postoperative complication (16% vs. 22 %, p = 0.374) and overall and disease-free survival between the two groups were not significantly different (p = 0.767 and p = 0.666, respectively).	Son, Taeil; Lee, Joong Ho; Kim, Yoo Min; Kim, Hyoung-Il; Noh, Sung Hoon; Hyung, Woo Jin. Robotic spleen-preserving total gastrectomy for gastric cancer: comparison with conventional laparoscopic procedure. Surg Endosc 2014;28(9):2606-2615.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Study concludes that robotic technique is feasible and outcomes are acceptable.
3	Other	514 (robotic n=120, laparoscopic n=394)	Robotic assisted gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operative blood loss, lymph node dissection, operation time	The robotic group had less intraoperative blood loss (118.3 ± 55.8 vs. 137.6 ± 61.6 ml, P < 0.001), more lymph nodes dissection (34.6 ± 10.9 vs. 32.7 ± 11.2, P = 0.013), and longer operation time (234.8 ± 42.4 vs. 221.3 ± 44.8 min, P = 0.003).	Survival - 1 and 2 years	The survival rates were 90.2% at 1 year, 78.1% at 2 years, and 67.8% at 3 years in the robotic assisted gastrectomy group compared with 87.3% at 1 year, 77.1% at 2 years, and 69.9% at 3 years in the laparoscopic gastrectomy group. The difference in overall survival rate between the two groups was not statistically significant (P = 0.812).	Junfeng, Zhou; Yan, Shi; Bo, Tang; Yingxue, Hao; Dongzhu, Zeng; Yongliang, Zhao; Feng, Qian; Peiwu, Yu. Robotic gastrectomy versus laparoscopic gastrectomy for gastric cancer: comparison of surgical performance and short-term outcomes. Surg Endosc 2014;28(6):1779-1787.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: Longer operative time in robotic group, less blood loss. No difference in survival at 1 or 2 years comparing the two groups.
3	Other	207	Robotic assisted gastrectomy Comparator: None	Clinical effectiveness of the intervention	Operative time, LOS	Mean operating time for all patients was 248.8 minutes, and mean length of hospitalization was 8.0 days.	-	-	Park, Ji Yeon; Kim, Young-Woo; Ryu, Keun Won; Eom, Bang Wool; Yoon, Hong Man; Reim, Daniel. Emerging Role of Robot-assisted Gastrectomy: Analysis of Consecutive 200 Cases. J Gastric Cancer 2013;13(4):255-262.	NA	NA	Population: Age information not given. Indication is stage I gastric cancer. Summary comments: This was a useful, small, observational study reporting on improvement in outcomes with learning curve and greater case volume. Operating time, retrieved lymph nodes, LOS improved in the latter cases in the series compared to the former. There is no comparison with laparoscopic.

3	Other	150 (robotic n=30, laparoscopic n=120)	Robotic assisted distal gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operative time	Median duration of operation was longer in the robotic group (218 minutes (interquartile range 200-254 minutes) versus 140 minutes (118-175 minutes) in the laparoscopic group; P < 0·001).	-	Costs	Park, J. Y.; Jo, M. J.; Nam, B.-H.; Kim, Y.; Eom, B. W.; Yoon, H. M.; Ryu, K. W.; Kim, Y.-W.; Lee, J. H.. Surgical stress after robot-assisted distal gastrectomy and its economic implications. Br J Surg 2012;99(11):1554-1561.	NA	NA	Population: Age information not given. Indication is gastric cancer. Summary comments: In this small observational study it was concluded that operative time was longer with robotic approaches, there was no difference in outcomes with respect to surgical stress and the cost of robotic surgery was higher than laparoscopic techniques.
3	Case series	827 (robotic n=236, laparoscopic n=591)	Robotic assisted distal gastrectomy Comparator: Laparoscopic gastrectomy	Clinical effectiveness of the intervention compared to existing interventions	Operative time	The mean operative time for the robotic group (219.5 minutes) was on average 49 minutes longer than the laparoscopic group (170.7 minutes) (P < .001)	Blood loss, morbidity and mortality, lymph node retrieval	Mean blood loss was significantly less in the robotic group (91.6 mL vs 147.9 mL; P = .002). The robotic group had mortality of 0.4% and morbidity of 11.0%, comparable with those of the laparoscopic group (P > .05). The number of lymph nodes retrieved per level was adequate in both groups and did not differ significantly.	Woo, Yanghee; Hyung, Woo Jin; Pak, Kyung-Ho; Inaba, Kazuki; Obama, Kazutaka; Choi, Seung Ho; Noh, Sung Hoon. Robotic gastrectomy as an oncologically sound alternative to laparoscopic resections for the treatment of early-stage gastric cancers. Arch Surg 2011;146(9):1086-1092.	NA	NA	Population: Average age 58 (laparoscopic) and 54 (robotic). Indication is early stage gastric cancer. Summary comments: The study concludes that robotic gastrectomy has better short-term and comparable oncologic outcomes compared with laparoscopic gastrectomy.

3	Case series	114	Robotic assisted thoracoscopic esophagectomy Comparator: None	Clinical effectiveness of the intervention	R0 resection rate	R0 resection was achieved in 111 patients (97.4%).	Mediastinal lymphadenectomy (ML)	Extended ML and total ML were performed in 24 (21.1%) and 90 (78.9%) patients respectively.	Park, S. Y.; Kim, D. J.; Yu, W. S.; Jung, H. S.. Robot-assisted thoracoscopic esophagectomy with extensive mediastinal lymphadenectomy: experience with 114 consecutive patients with intrathoracic esophageal cancer. Dis. Esophagus 2015;0(0):0.	90-day mortality was observed in three patients (2.5%)	NA	Population: Average age - 63. Indication is oesophageal cancer. Summary comments: Authors conclude that robotically assisted thoracoscopic oesophagectomy can be performed safely with acceptable post operative outcomes, and that longer term follow-up should assess the oncological outcome of the procedure. There was no comparator group.

Appendix Two

Literature search terms

Assumptions / limits applied to search:	
Original search terms:	robotics da Vinci
Updated search terms - Population	Oesophago-gastric oesophagus Esophageal stomach gastric neoplasm* cancer*
Updated search terms - Intervention	Robotic Robotics da Vinci Robotically-assisted Robotically assisted Robotic-assisted Robot assisted Robot-assisted Computer assisted Computer-assisted Remote Operations Telerobotics
Updated search terms - Comparator	gastrectom* oesophagectom* esophagectom* laparoscopic open
Updated search terms - Outcome	Additional search carried out for learning curve

Inclusion criteria	**General inclusion criteria**
	In order of decreasing priority, articles will be selected based on the following criteria. 1.All relevant systematic reviews and meta-analysis in the last 5 years and those in 5-10 years period which are still relevant (e.g. no further updated systematic review available) 2.All relevant RCTs and those in the 5-10 years period which are still relevant (e.g. not superseded by a next phase of the trial/ the RCT is one of the few or only high quality clinical trials available) >>>> If studies included reaches 30, inclusion stops here 3.All relevant case control and cohort studies, that qualify after exclusion criteria >>>> If studies included reaches 30, inclusion stops here 4.All relevant non analytical studies (case series/ reports etc.) that qualify after exclusion criteria >>>> If studies included reaches 30, inclusion stops here
	Specific inclusion criteria
	-
Exclusion criteria	**General exclusion criteria**
	Studies with the following characteristics will be excluded: 1. Does not answer a PICO research question 2. Comparator differs from the PICO 3. < 50 subjects (where studies with >50 subjects exist) 4. No relevant outcomes 5. Incorrect study type 6. Inclusion of outcomes for only one surgeon/doctor or only one clinical site (where studies with > one surgeon/doctor or one clinical site exist) 7. Narrative / non-systematic reviews (relevant referenced studies to be included)
	Specific exclusion criteria
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