Multi-port robotic assisted (Da Vinci) laparoscopic myomectomy: a systematic review and meta-analysis of comparative clinical and fertility outcomes.

Elias Tsakos[1], Emmanouil Xydias[1], Apostolos C. Ziogas[1], Felice Sorrentino [1], Luigi Nappia [1], Nikolaos Vlachos[1], and Aggelos Daniilidis[1]

[1]Affiliation not available

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Elias Tsakos[1,2], Emmanouil M. Xydias[1,2,3], Apostolos C. Ziogas[2,3], Felice Sorrentino[4], Luigi Nappia[4], Nikolaos Vlachos[5], Aggelos Daniilidis[6]

1: EmbryoClinic IVF, Thessaloniki, Greece

2: Hellenic medical Research Institute (HMRI), Thessaloniki, Greece

3: University of Thessaly, School of Health Sciences, Faculty of Medicine, Larissa, Greece

4: Institute of Obstetrics and Gynecology, University of Foggia, Italy

5: National and Kapodistrial University of Athens, School of Medicine, Department of Obstetrics and Gynaecology

6: Aristotle University of Thessaloniki, School of Medicine, Thessaloniki, Greece

Abstract

Introduction

Uterine fibroids are amongst the most frequent gynaecologic disorders encountered in clinical practice and are most effectively treated surgically. This study aims to assess which myomectomy method, namely robotic, laparoscopic or abdominal, is the most effective and safe choice.

Methods and materials

Relevant studies were systematically sought in peer-reviewed medical research databases. The initial pool of 955 studies was evaluated and reduced to 53, which adhered to the pre-established inclusion criteria, 25 of which were comparative ones. The studies were subsequently evaluated for risk of bias and statistical heterogeneity.

Results

The available comparative studies were compared using surgical outcomes, namely blood loss, complication rate, transfusion rate, operation duration, conversion to laparotomy and length of hospitalization. Robotic assisted laparoscopic myomectomy was significantly superior to abdominal myomectomy in all assessed parameters, other than operation duration. Robotic and conventional laparoscopic myomectomy performed similarly in most parameters, however the robotic approach reduced intra-operative bleeding in patients with small fibroids and had lower conversion to laparotomy rates, resulting in a safer overall approach.

Conclusion

The robotic approach for uterine fibroids management is a safe, effective and viable approach, which is constantly improving and in time may surpass its current drawbacks. Further research is required, in particular randomized studies to provide further insight into the subject.

Keywords: myomectomy, Da Vinci, robotic gynaecologic surgery, uterine fibroids, minimally invasive

Introduction

Uterine fibroids, also referred to as leiomyomas or simply myomas, are among the most prevalent gynaecological disorders, with ultrasonographic findings indicative of their presence being detected in up to 80% of women by the age of 50 years (*1*). While in their majority remain asymptomatic and are diagnosed incidentally (*2*), uterine fibroids may cause manifestations such as pelvic pain, abnormal uterine bleeding, dysmenorrhea and mass effect, leading to disturbed urinary, gastrointestinal and sexual dysfunction. More insidiously, they may also be the cause of secondary infertility, emotional distress, anxiety or depression, with a significant effect on overall quality of life (*3*).

Considering the above, effective treatment is paramount, not only for symptom alleviation, but also to improve future fertility prospects. While a plethora of non-invasive options for myoma management are available, surgical treatment remains the gold standard (*4*) with minimally invasive surgery in particular offering considerable advantages and being most frequently the preferred option (*5*). Amongst the most advanced minimally invasive options is robotic assisted laparoscopic myomectomy (RALM) with the use of the Da Vinci Surgical System, offering impressive three dimensional visualization capabilities, natural, wrist-like control of surgical instruments and superior ergonomics (*6*). These technical advantages in theory contribute to the increase of intra-operative efficiency, control and safety and thus to improved surgical outcomes with fewer complications and morbidity. In this systematic review we will examine this hypothesis, namely whether these technical advantages improve RALM's safety and effectiveness of conventional laparoscopic myomectomy (CLM) and abdominal myomectomy (AM).

Methods and Materials

This is a systematic review conducted based on pre-established criteria and on the methodology suggested by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) recommendations (*7*).

Eligibility criteria

The research question at the core of this review was structured using the PICOS (population-intervention-comparator-outcome-study design) format, in order to ensure that the sought data and outcomes were precisely defined beforehand, a strategy also supported by the recommendations of the Cochrane Collaboration (*8*). The target population of this review were women with uterine fibroids, regardless of clinical manifestations, who received surgical treatment of said fibroids. This study excluded pediatric populations and mesenchymal tumors arising at different anatomical regions. The intervention investigated was Robotic Assisted Laparoscopic Myomectomy (RALM). Given the rise of various surgical platforms and methodologies (*9-11*), the investigated intervention was further refined to the multi-port variant, defined as the use of at least one robotic port for camera placement and two additional robotic ports for the robotic arms and instruments, with the optional third robotic port and/or accessory port(s). Furthermore, the investigated robotic platform was the Da Vinci Surgical System, given both its prevalence in the available literature, as well as for the sake of methodological homogeneity.

Comparators were not mandatory for study inclusion, however were crucial for comparative meta-analysis; thus Conventional Laparoscopic Myomectomy (CLM) and Abdominal Myomectomy (AM) were both included as eligible comparators. The primary sought outcomes of this study were the metrics of surgical performance consistent enough in the available literature to facilitate comparison of the approaches; namely mean operation duration (MOD), estimated blood loss (EBL), hospitalization duration or length of stay (LOS), transfusion rate, complication rate and conversion to laparotomy rate for RALM and CLM. Secondary outcomes included symptom improvement and fertility outcomes for women wishing to conceive post-operatively. Acceptable study designs were either prospective or retrospective case series, cohorts, case-control studies and clinical trials. Single case reports or secondary studies were excluded from this analysis.

Search methodology and data sources

Studies relevant to our research question were sought on the peer-reviewed medical research MEDLINE/PubMed, Web of Science and Scopus, with the most recent search having been conducted on 11/01/2023. The same search terms were used on all three databases: (robotic OR "robotic assisted" OR "robotic-assisted") AND (myomectomy OR fibroidectomy). No search limitations or additional automated search filters were utilized during this process.

Selection methodology and extracted data

The resulting initial study pool was evaluated independently by two teams of authors, who followed the same steps. Initially, duplicate records were removed, with the remaining records being screened for relevance, the most promising of which being moved to full-text assessment. Disagreements between the two independent teams were reviewed and resolved, with the included articles ultimately being agreed upon by all co-authors. Data on study design (study period, type of study, total sample size, year of publication), patients' characteristics (mean age, mean BMI etc), myoma characteristics (mean number, weight, diameter etc), RALM characteristics (Da Vinci model, methodology, trocars used etc) and comparators were extracted and organized.

With regard to sought outcomes, data on MOD, EBL, LOS, complication rates, transfusion rates and conversion rates were extracted and utilized for meta-analysis. Additional data on fertility were also extracted, organized and are presented for the purposes of this review, although not in the form of meta-analysis.

Risk of bias assessment

To facilitate assessment of risk of bias amongst the included studies, tools tailored to each studies design were used from the NIH website (*12*). Based on each study's performance at each of the examined domains, an overall verdict of "Good" quality would be given if more than two thirds of the signaling questions had a positive answer, a "Fair" quality if half to two thirds did so and "Poor" in case less than half did so. Studies were assessed once again independently by the authors and an ultimate consensus was reached for each one.

Statistical analysis

Statistical heterogeneity between the studies was evaluated with the use of the I2 statistic, as formally suggested in the Cochrane Handbook for systematic reviews (*8*). A I2 $< 50\%$ and a p value over 0.05 were considered non-significant heterogeneity. Meta-analysis was conducted with the results being either pooled percentages or standardized mean difference (SDM) of the meta-analysed outcomes during comparisons. As per the most widely accepted definitions, difference amongst the assessed parameters was evaluated as small for SMD $= 0.2$; medium for SMD $= 0.5$; and large for SMD $= 0.8$, with $p<0.05$ being considered statistically significant for all comparisons (*13* ,*14*). Where possible and most relevant, forest plots were constructed to facilitate visualization of the assessed corelations, otherwise data was provided in text, tables or supplementary material. Calculations and graphs were carried out using the Stata Statistical Software: Release 14.2 by StataCorp LP.

Results

The initial pool of 955 studies, which resulted from the preliminary search of the medical databases was refined via manual screening of the title and abstract, leading to 107 reports being moved to full-text assessment. Through constant evaluation and strict application of the pre-established inclusion criteria, 53 studies were ultimately included in this review (*15-67*). This systematic process of selection is summarized on **Figure 1** . Most of the eligible studies originated from the USA, the Republic of Korea and Taiwan and the vast majority were based on data collected retrospectively from institutional medical records, with only 8 studies being conducted prospectively. 25 of the studies utilized an eligible comparator; CLM, AM or both, thus were utilized in comparative analysis. Ultimately, this systematic review included data from 7109 women. This information is summarized on **Table 2** .

The mean age of the included participants ranged from 34 to 48.2 and mean BMI from 20.2 to 31. The main indications for myomectomy were clinical symptoms such as feeling of pelvic mass, pelvic pain, uterine bleeding, infertility, gastrointestinal symptoms, urinary symptoms etc and a sizeable percentage of participants had a history of prior abdominal surgery and/or caesarean section **(Table 3)** . With regard to RALM technical characteristics, the majority of available studies used older Da Vinci Surgical System, with only 9 studies using the 4^{th} generation Da Vinci X and Xi systems. With regard to the procedure, the basic steps were consistent amongst all studies. Most studies used a 12mm robotic port for the camera, placed either above or below the umbilicus, with at least 2 additional, most commonly 8mm robotic ports bilaterally. A few studies used a third 8mm robotic port and most researchers used an accessory 12, 10 or 5mm port as well. The mean number of robotically excised myomas per study ranged from 1.5 to 7, as did the mean myoma diameter (3-8.3 cm), the mean diameter of the largest myoma (5-11cm) and mean myoma weight (30-450 g) **(Table 4)** .

With regard to risk of bias, the included studies were assessed using the tools for case series, case-control and non-randomized trials, recommended by the NIH (*12*). Based on the results of this analysis, 38 (72%) of the included studies were of "Good" quality with regard to risk of bias, 8 studies (15%) were of "Fair" quality and the remaining 7 studies (13%) were of "Poor" quality with regard to risk of bias assessment.

Heterogeneity among the studies was assessed using the I^2 index. Regarding the RALM and AM comparison of primary surgical outcomes, there was statistically significant heterogeneity, namely I^2=81.5% ($p<0.001$) for the EBL comparison, I^2=83.2% ($p<0.001$) for the MOD comparison and I^2=95.3% ($p<0.001$) for the LOS comparison. Heterogeneity was non-significant for the complication rate comparison (I^2=0%, p=0.716) and for the transfusion rate comparison (I^2=0%, p=0.418). With regard to actual outcomes, RALM had significantly lower EBL compared to AM, with SMD=0.312, p=0.004 **(Figure 2a)** , AM was superior with regard to MOD, requiring significantly less operation time, with SMD=1.251, $p<0.001$ **(Figure 2b)** and RALM necessitated significantly less hospitalization duration than AM, with the LOS SMD=1.368, $p<0.001$ **(Figure 2c)** . RALM had a significantly lower complication rate compared to AM, being nearly 70% safer, with OR=0.669, p=0.016 **(Figure 3a)** , in addition to a 40% less frequent requirement of transfusion compared to AM, with a pooled OR=0.402, $p<0.001$ **(Figure 3b)** .

For the comparison of RALM to CLM, data was stratified in groups based on overall myoma weight, so as to more thoroughly elucidate any possible applications of each methodology based on myoma burden. Statistical heterogeneity was assessed for each comparison and was significant, with I^2=87.6%, $p<0.001$ for the EBL comparison, I^2=96.6%, $p<0.001$ for the MOD comparison and I^2=72.2%, $p<0.001$. Heterogeneity was non-significant for the complication rate comparison (I^2=0%, p=0.596), the transfusion rate comparison (I^2=18.2%, p=0.266) and the conversion to laparotomy rate comparison (I^2=0%, p=0.781). With regard to outcomes, there was no statistically significant difference with regard to EBL between RALM and CLM (SMD=0.079, p=0.544), however, when data was stratified according to myoma weight, RALM caused significantly less blood loss in cases with lower myoma weight (SMD=0.272, p=0.025), while CLM was superior for the rest of the myoma cases, SMD=0.49, p=0.007**(Figure 4a)** . Similar to the RALM-AM comparison, RALM was inferior to CLM with regard to MOD, SMD=0.97, p<0.001**(Figure 4b)** , while there were no statistically significant differences between the two methods with regard to LOS, SMD=0.172, p=0.094 **(Figure 4c)** . Complication and transfusion rates were similar in both methods, with no statistically significant differences, SMD=0.842, p=0.596 and SMD=0.984, p=0.951 respectively **(Figure 5a and 5b)** . Conversion to laparotomy rate also technically showed no statistically significant difference between the two methods, however the difference was only marginally non-significant, with OR=0.533 and p=0.058 **(Figure 5c)** .

With regard to fertility outcomes, pregnancy rates ranged from 50-80% post-operatively, with the majority originating from spontaneous conception. Studies with sufficient follow-up, at the time of publication, demonstrated a live birth rate of 25-100%. Detailed fertility and obstetric outcomes are summarized on **Table 1** .

Discussion

In this systematic review, we examined the application of RALM, one of the newest minimally invasive available techniques for the treatment of uterine fibroids and compared it to the other two established methodologies, namely AM and CLM. All available studies with data on RALM was collected and the information extracted on tables. RALM was compared to AM favourably in almost all aspects apart from operation duration. Operation duration was also more favourable in CLM than RALM, with the rest of the assessed outcomes not being significantly different between the two methods. The exceptions to that were EBL for lesser myoma burden patients, which was significantly more favourable in RALM and conversion to AM rate, which only marginally lacked statistical significance.

The findings of the present systematic review are indicative of the wider trend of minimally invasive surgery expansion and proliferation in more and more fields of Gynaecologic Surgery. Our findings with regard to AM and RALM comparison are in complete agreement with Wang et al (*68*), who conducted a similar meta-analysis in 2018. However, there are differences when the comparison of RALM and CLM is concerned. In their analysis, as was the case in ours as well, Wang et al showed that there were no statistically significant differences in transfusion rates or LOS between RALM and CLM (*68*). Additionally, they showed that there was a statistically significant difference in conversion to laparotomy rate (*68*) between the two methods. In our analysis, while conversion rate difference was non-significant, this was only by a very small margin, thus findings on conversion rate are in actuality quite similar. Wang et al also showed statistically significant differences in complication rates, although when complications were analyzed in subgroups, the differences were non-significant, similar to our general observations with regard to complications. Another difference between the two analyses was with regard to EBL, as Wang et al. showed there was a statistically significant difference between RALM and CLM, regardless of other conditions. This held true in our analysis only for lower overall myoma burden patients, with the overall differences not being statistically significant. Finally, with regard to operative time, Wang et al. showed that there were no statistically significant differences, while in our analysis CLM was significantly faster. However, regarding this particular comparison, in the meta-analysis by Wang et al, the difference was only marginally statistically significant (*68*).

These differences between the two studies may be attributed to differences in baseline characteristics of the patients, as in multiple studies the two groups had statistically significant difference with regard to myoma number, size, weight etc. Additionally, since the more modern studies also included patients operated on using the latest Da Vinci surgical system platforms, the observed discrepancies may be attributed to inexperience of the surgeon or the ancillary staff for these first reported cases. Furthermore, in both analyses, there was statistically significant heterogeneity amongst the included primary comparisons, thus the results of the meta-analysis might be affected in both cases.

With regard to the findings of the present study, the apparent disadvantage of RALM versus CLM, namely the unfavourable comparison to the other two methods with regard to operation duration, while indeed constituting a notable drawback, may be acceptable if patient risk of morbidity and mortality is significantly reduced in return. Additionally, based on the data collected during the present study, RALM operation duration is following a downward trend already **(Figure 6)** , and is likely to continue to do so in the future given the continuous growth of robotic technology (*69*) and improvement of training standards. When the inevitable comparison to CLM is made, RALM proved to be superior with regard to EBL in patients with smaller overall myoma weights. These cases usually include patients with smaller myomas, a situation where the absolute control and precision that the robotic surgical system offers is best utilized, minimizing injuries and thus resulting in reduced blood loss. Additionally, the fact that RALM offered up to 50% reduced risk of conversion to laparotomy, a complication associated with further, severe complications and an overall more adverse outcome (*70*); reinforces the safety and risk minimization aspect emphasized by robotic technology.

Robotic surgery has been a rapidly developing field in recent years, particularly as far as Gynaecological Surgery is concerned. The robotic equipment was designed to surpass the limitation of conventional laparoscopy, providing superior, three-dimensional visualization of the surgical site, increased magnification of areas of interest, enhanced dexterity via highly articulating surgical instruments and absent tremor (*71* ,*72*). Additionally, the ergonomic working configuration of the console ensures reduced strain, be it physical or mental, to the surgeon, with significant improvement to surgery ergonomics (*73* ,*74*), a vital feature especially for high-volume surgeons and/or multi-hour procedures. Given the prevalence of uterine fibroids and the effect that they may have on quality of life and fertility, a safe, effective, reliable and ergonomic approach such as RALM is a necessary and beneficial addition to the modern Gynaecologic Surgeon's arsenal (*75*).

Research on the applicability of robotic systems in Gynaecologic Surgery, and in fibroid management in particular, is still lacking. Future research projects should aim to design a randomized trial for RALM and CLM comparison, as such a study has not been conducted yet and would provide valuable insight. Additionally, further specialized applications and indications for robotic surgery should be sought, as such data may be utilized in updating management algorithms and promote robotic surgery to patients who truly stand to gain the most from this advanced method.

The present study does come with certain limitations, which should be acknowledged. Firstly, there was statistically significant heterogeneity in the pooled available data, which may have introduced bias, affecting the results of the analysis. Additionally, there were not enough studies utilizing the latest advances in robotic technology, i.e. 4^{th} generation Da Vinci surgical systems, which may be more representative of the capabilities of modern systems, since robotics is such a rapidly evolving field. Finally, not enough primary data was available to further stratify patients and thus to test the performance of the three therapeutic approaches in more specific cases.

Conclusion

RALM is a safe and effective therapeutic option for uterine fibroids, which is superior to AM in almost every regard and offers significant risk reduction and safety over CLM. Robotic technology, as well as surgical skill is likely to further improve in the future, thus enhancing the benefits already offered by this technology. Further primary research should focus on establishing patient subgroups which would most benefit from this advanced methodology.

References

1. Baird DD, Dunson DB, Hill MC, Cousins D, Schectman JM. High cumulative incidence of uterine

leiomyoma in black and white women: ultrasound evidence. Am J Obstet Gynecol. 2003;188(1):100-7.

2. Giuliani E, As-Sanie S, Marsh EE. Epidemiology and management of uterine fibroids. Int J Gynaecol Obstet. 2020;149(1):3-9.

3. Ghant MS, Sengoba KS, Recht H, Cameron KA, Lawson AK, Marsh EE. Beyond the physical: a qualitative assessment of the burden of symptomatic uterine fibroids on women's emotional and psychosocial health. J Psychosom Res. 2015;78(5):499-503.

4. Sabry M, Al-Hendy A. Medical treatment of uterine leiomyoma. Reprod Sci. 2012;19(4):339-53.

5. Flyckt R, Coyne K, Falcone T. Minimally Invasive Myomectomy. Clin Obstet Gynecol. 2017;60(2):252-72.

6. Moon AS, Garofalo J, Koirala P, Vu MT, Chuang L. Robotic Surgery in Gynecology. Surg Clin North Am. 2020;100(2):445-60.

7. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.

8. Reitsma JB RA, Whiting P, Vlassov VV, Leeflang MMG, Deeks JJ. Chapter 9: Assessing methodological quality. 2009. In: Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy Version 100 [Internet].*http://srdta.cochrane.org/*: The Cochrane Collaboration.

9. Alip SL, Kim J, Rha KH, Han WK. Future Platforms of Robotic Surgery. Urol Clin North Am. 2022;49(1):23-38.

10. Dobbs RW, Halgrimson WR, Talamini S, Vigneswaran HT, Wilson JO, Crivellaro S. Single-port robotic surgery: the next generation of minimally invasive urology. World J Urol. 2020;38(4):897-905.

11. Guo N, Liu H. Robotic laparoendoscopic single-site gynecologic surgery. Asian J Surg. 2022;45(8):1644-5.

12. Study Quality Assessment Tools National Heart Lung and Blood Institute [Available from:*https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools*.

13. Takeshima N, Sozu T, Tajika A, Ogawa Y, Hayasaka Y, Furukawa TA. Which is more generalizable, powerful and interpretable in meta-analyses, mean difference or standardized mean difference? BMC Med Res Methodol. 2014;14:30.

14. Lin L, Aloe AM. Evaluation of various estimators for standardized mean difference in meta-analysis. Stat Med. 2021;40(2):403-26.

15. Advincula AP, Xu X, Goudeau St, Ransom SB. Robot-assisted laparoscopic myomectomy versus abdominal myomectomy: a comparison of short-term surgical outcomes and immediate costs. J Minim Invasive Gynecol. 2007;14(6):698-705.

16. Aendekerk S, Verguts J, Housmans S, Timmerman D. Implementing robotic assisted myomectomy in surgical practice - a retrospective cohort study. Gynecol Surg. 2019;16.

17. Ahn SH, Park JH, Kim HR, Cho SH, Lee M, Seo SK, et al. Robotic single-site versus multi-port myomectomy: a case–control study. BMC Surg. 2021;21(1).

18. Ascher-Walsh CJ, Capes TL. Robot-assisted Laparoscopic Myomectomy Is an Improvement Over Laparotomy in Women with a Limited Number of Myomas. J Minimally Invasive Gynecol. 2010;17(3):306-10.

19. Barakat EE, Bedaiwy MA, Zimberg S, Nutter B, Nosseir M, Falcone T. Robotic-assisted, laparoscopic, and abdominal myomectomy: a comparison of surgical outcomes. Obstet Gynecol. 2011;117(2 Pt 1):256-66.

20. Bedient CE, Magrina JF, Noble BN, Kho RM. Comparison of robotic and laparoscopic myomectomy. Am J Obstet Gynecol. 2009;201(6).

21. Cela V, Freschi L, Simi G, Tana R, Russo N, Artini PG, et al. Fertility and endocrine outcome after robot-assisted laparoscopic myomectomy (RALM). Gynecol Endocrinol. 2013;29(1):79-82.

22. Chen CH, Chen HH, Liu WM. Complication reports for robotic surgery using three arms by a single surgeon at a single institution. J Minimal Access Surg. 2017;13(1):22-8.

23. Chen YC, Lin HH, Hsiao SM. Comparison of robotic assisted laparoscopic myomectomy with barbed sutures and traditional laparoscopic myomectomy with barbed sutures. TAIWANESE JOURNAL OF OBSTETRICS & GYNECOLOGY. 2018;57(5):709-12.

24. Cheng HY, Chen YJ, Wang PH, Tsai HW, Chang YH, Twu NF, et al. Robotic-assisted laparoscopic complex myomectomy: A single medical center's experience. TAIWANESE JOURNAL OF OBSTETRICS & GYNECOLOGY. 2015;54(1):39-42.

25. Choi SH, Hong S, Kim M, Bae HS, Kim MK, Kim ML, et al. Robotic-assisted laparoscopic myomectomy: The feasibility in single-site system. Obstet Gynecol Sci. 2019;62(1):56-64.

26. Flyckt R, Soto E, Nutter B, Falcone T. Comparison of Long-Term Fertility and Bleeding Outcomes after Robotic-Assisted, Laparoscopic, and Abdominal Myomectomy. Obstet Gynecol Int. 2016;2016.

27. Göçmen A, Şanlıkan F, Uçar MG. Comparison of robotic-assisted laparoscopic myomectomy outcomes with laparoscopic myomectomy. Arch Gynecol Obstet. 2013;287(1):91-6.

28. Goetgheluck J, Carbonnel M, Ayoubi JM. Robotically Assisted Gynecologic Surgery: 2-Year Experience in the French Foch Hospital. Front Surg. 2014;1.

29. Goldberg HR, McCaffrey C, Amjad H, Kives S. Fertility and Pregnancy Outcomes After Robotic-assisted Laparoscopic Myomectomy in a Canadian Cohort. J Minimally Invasive Gynecol. 2022;29(1):72-6.

30. Griffin L, Feinglass J, Garrett A, Henson A, Cohen L, Chaudhari A, et al. Postoperative Outcomes After Robotic Versus Abdominal Myomectomy. JSLS-JOURNAL OF THE SOCIETY OF LAPAROENDOSCOPIC SURGEONS. 2013;17(3):407-13.

31. Gunnala V, Setton R, Pereira N, Huang JQ. Robot-Assisted Myomectomy for Large Uterine Myomas: A Single Center Experience. Minim Invasive Surg. 2016;2016:4905292.

32. Hanafi M. Comparative study between robotic laparoscopic myomectomy and abdominal myomectomy. Middle East Fertil Soc J. 2014;19(4):268-73.

33. Hsiao SM, Lin HH, Peng FS, Jen PJ, Hsiao CF, Tu FC. Comparison of robot-assisted laparoscopic myomectomy and traditional laparoscopic myomectomy. J Obstet Gynaecol Res. 2013;39(5):1024-9.

34. Jansen LJ, Clark NV, Dmello M, Gu XM, Einarsson JI, Cohen SL. Perioperative Outcomes of Myomectomy for Extreme Myoma Burden: Comparison of Surgical Approaches. J Minimally Invasive Gynecol. 2019;26(6):1095-103.

35. Kang SY, Jeung IC, Chung YJ, Kim HK, Lee CR, Mansukhani TS, et al. Robot-assisted laparoscopic myomectomy for deep intramural myomas. Int J Med Rob Comput Assisted Surg. 2017;13(2).

36. Asmar J, Even M, Carbonnel M, Goetgheluck J, Revaux A, Ayoubi JM. Myomectomy by Robotically Assisted Laparoscopic Surgery: Results at Foch Hospital, Paris. Front Surg. 2015;2:40.

37. Kim H, Shim S, Hwang Y, Kim M, Hwang H, Chung Y, et al. Is robot-assisted laparoscopic myomectomy limited in multiple myomas?: A feasibility for ten or more myomas. Obstet Gynecol Sci. 2018;61(1):135-41.

38. Kim JM, Lee YH, Chong GO, Lee SR, Hong DG. Comparison of Multi- and Single-Site Robotic Myomectomy Using the Da Vinci (R) SP Surgical System: A Propensity Score Matching Analysis. J Clin Med. 2022;11(23).

39. Lee CY, Chen IH, Torng PL. Robotic myomectomy for large uterine myomas. TAIWANESE JOURNAL OF OBSTETRICS & GYNECOLOGY. 2018;57(6):796-800.

40. Lee SR, Kim JH, Kim S, Kim SH, Chae HD. The Number of Myomas Is the Most Important Risk Factor for Blood Loss and Total Operation Time in Robotic Myomectomy: Analysis of 242 Cases. J Clin Med. 2021;10(13).

41. Lee SR, Kim JH, Lee YJ, Lee SW, Park JY, Suh DS, et al. Single-Incision versus Multiport Robotic Myomectomy: A Propensity Score Matched Analysis of Surgical Outcomes and Surgical Tips. J Clin Med. 2021;10(17).

42. Lee SR, Lee ES, Lee YJ, Lee SW, Park JY, Kim DY, et al. Robot-Assisted Laparoscopic Myomectomy versus Abdominal Myomectomy for Large Myomas Sized over 10 cm or Weighing 250 g. Yonsei Med J. 2020;61(12):1054-9.

43. Lonnerfors C, Persson J. Pregnancy following robot-assisted laparoscopic myomectomy in women with deep intramural myomas. Acta Obstet Gynecol Scand. 2011;90(9):972-7.

44. Mansour FW, Kives S, Urbach DR, Lefebvre G. Robotically Assisted Laparoscopic Myomectomy: A Canadian Experience. J Obstet Gynaecol Can. 2012;34(4):353-8.

45. Moawad GN, Tyan P, Paek J, Tappy EE, Park D, Choussein S, et al. Comparison between single-site and multiport robot-assisted myomectomy. J Rob Surg. 2019;13(6):757-64.

46. Morales HSG, Lopez RR, Lopez GGP, Mondragon PJC, Cortes DV, Hernandez HS, et al. Surgical approach to uterine myomatosis in patients with infertility: open, laparoscopic, and robotic surgery; results according to the quantity of fibroids. J Bras Reproducao Assistida. 2022;26(1):44-9.

47. Movilla P, Orlando M, Wang J, Opoku-Anane J. Predictors of Prolonged Operative Time for Robotic-Assisted Laparoscopic Myomectomy: Development of a Preoperative Calculator for Total Operative Time. J Minimally Invasive Gynecol. 2020;27(3):646-54.

48. Nam SH, Paek J, Choi C, Nam SH, Kim WY. A comparison between reduced-port robotic surgery and multiport robot-assisted laparoscopy for myomectomy. EUROPEAN JOURNAL OF OBSTETRICS & GYNECOLOGY AND REPRODUCTIVE BIOLOGY. 2017;213:53-7.

49. Nash K, Feinglass J, Zei C, Lu GN, Mengesha B, Lewicky-Gaupp C, et al. Robotic-assisted laparoscopic myomectomy versus abdominal myomectomy: a comparative analysis of surgical outcomes and costs. Arch Gynecol Obstet. 2012;285(2):435-40.

50. Nezhat C, Lavie O, Hsu SZ, Watson J, Barnett O, Lemyre M. Robotic-assisted laparoscopic myomectomy compared with standard laparoscopic myomectomy-a retrospective matched control study. Fertil Steril. 2009;91(2):556-9.

51. Özbaşlı E, Güngör M. Comparison of perioperative outcomes among robot-assisted, conventional laparoscopic, and abdominal/ open myomectomies. J Turkish German Gynecol Assoc Artemis. 2021;22(4):312-8.

52. Park KM, Kang S, Kim C, Sung Y, Chung YJ, Song J, et al. Variables that prolong total operative time for robotic-assisted laparoscopic myomectomy: A 10-year tertiary hospital study in Korea. EUROPEAN JOURNAL OF OBSTETRICS & GYNECOLOGY AND REPRODUCTIVE BIOLOGY. 2021;262:62-7.

53. Park SY, Moon HS, Kim J, Jeong K, Hur YM, Cho EH, et al. Clinical experience of robotic myomectomy for fertility preservation using preoperative magnetic resonance imaging predictor. Obstet Gynecol Sci. 2020;63(6):726-34.

54. Piquion-Joseph JM, Nayar A, Ghazaryan A, Papanna R, Klimek W, Laroia R. Robot-assisted gynecological surgery in a community setting. J Rob Surg. 2009;3(2):61-4.

55. Pitter MC, Gargiulo AR, Bonaventura LM, Stefano Lehman J, Srouji SS. Pregnancy outcomes following robot-assisted myomectomy. Hum Reprod. 2013;28(1):99-108.

56. Pitter MC, Srouji SS, Gargiulo AR, Kardos L, Seshadri-Kreaden U, Hubert HB, et al. Fertility and Symptom Relief following Robot-Assisted Laparoscopic Myomectomy. Obstet Gynecol Int. 2015;2015:967568.

57. Pluchino N, Litta P, Freschi L, Russo M, Simi G, Santoro AN, et al. Comparison of the initial surgical experience with robotic and laparoscopic myomectomy. Int J Med Rob Comput Assisted Surg. 2014;10(2):208-12.

58. Sangha R, Eisenstein DI, George A, Munkarah A, Wegienka G. Surgical outcomes for robotic-assisted laparoscopic myomectomy compared to abdominal myomectomy. J Rob Surg. 2010;4(4):229-33.

59. Sheu BC, Huang KJ, Huang SC, Chang WC. Comparison of uterine scarring between robot-assisted laparoscopic myomectomy and conventional laparoscopic myomectomy. J Obstet Gynaecol. 2020;40(7):974-80.

60. Takmaz O, Ozbasli E, Gundogan S, Bastu E, Batukan C, Dede S, et al. Symptoms and Health Quality After Laparoscopic and Robotic Myomectomy. JSLS-JOURNAL OF THE SOCIETY OF LAPAROENDOSCOPIC SURGEONS. 2018;22(4).

61. Tan SJ, Lin CK, Fu PT, Liu YL, Sun CC, Chang CC, et al. Robotic surgery in complicated gynecologic diseases: Experience of Tri-Service General Hospital in Taiwan. TAIWANESE JOURNAL OF OBSTETRICS & GYNECOLOGY. 2012;51(1):18-25.

62. Tusheva OA, Gyang A, Patel SD. Reproductive outcomes following robotic-assisted laparoscopic myomectomy (RALM). J Robot Surg. 2013;7(1):65-9.

63. Won S, Choi SH, Lee N, Shim SH, Kim MK, Kim ML, et al. Robotic Single-Site Plus Two-Port Myomectomy versus Conventional Robotic Multi-Port Myomectomy: A Propensity Score Matching Analysis. J Pers Med. 2022;12(6).

64. Won S, Lee N, Kim M, Kim MK, Kim ML, Jung YW, et al. Comparison of operative time between robotic and laparoscopic myomectomy for removal of numerous myomas. Int J Med Rob Comput Assisted Surg. 2020;16(6):1-5.

65. Yim GW, Kim SW, Nam EJ, Kim S, Kim YT. Perioperative Complications of Robot-Assisted Laparoscopic Surgery Using Three Robotic Arms at a Single Institution. Yonsei Med J. 2015;56(2):474-81.

66. George A, Eisenstein D, Wegienka G. Analysis of the Impact of Body Mass Index on the Surgical Outcomes after Robot-Assisted Laparoscopic Myomectomy. J Minimally Invasive Gynecol. 2009;16(6):730-3.

67. Huberlant S, Lenot J, Neron M, Ranisavljevic N, Letouzey V, De Tayrac R, et al. Fertility and obstetrical outcomes after robot-assisted laparoscopic myomectomy. Int J Med Rob Comput Assisted Surg. 2020;16(1).

68. Wang T, Tang H, Xie Z, Deng S. Robotic-assisted vs. laparoscopic and abdominal myomectomy for treatment of uterine fibroids: a meta-analysis. Minim Invasive Ther Allied Technol. 2018;27(5):249-64.

69. Horn D, Sacarny A, Zhou A. Technology adoption and market allocation: The case of robotic surgery. J Health Econ. 2022;86:102672.

70. Lim CS, Mowers EL, Mahnert N, Skinner BD, Kamdar N, Morgan DM, et al. Risk Factors and Outcomes for Conversion to Laparotomy of Laparoscopic Hysterectomy in Benign Gynecology. Obstet Gynecol. 2016;128(6):1295-305.

71. Lanfranco AR, Castellanos AE, Desai JP, Meyers WC. Robotic surgery: a current perspective. Ann Surg. 2004;239(1):14-21.

72. Mucksavage P, Kerbl DC, Lee JY. The da Vinci(®) Surgical System overcomes innate hand dominance. J Endourol. 2011;25(8):1385-8.

73. Heemskerk J, Zandbergen HR, Keet SW, Martijnse I, van Montfort G, Peters RJ, et al. Relax, it's just laparoscopy! A prospective randomized trial on heart rate variability of the surgeon in robot-assisted versus conventional laparoscopic cholecystectomy. Dig Surg. 2014;31(3):225-32.

74. Hubert N, Gilles M, Desbrosses K, Meyer JP, Felblinger J, Hubert J. Ergonomic assessment of the surgeon's physical workload during standard and robotic assisted laparoscopic procedures. Int J Med Robot. 2013;9(2):142-7.

75. Arian SE, Munoz JL, Kim S, Falcone T. Robot-assisted laparoscopic myomectomy: current status. Robot Surg. 2017;4:7-18.

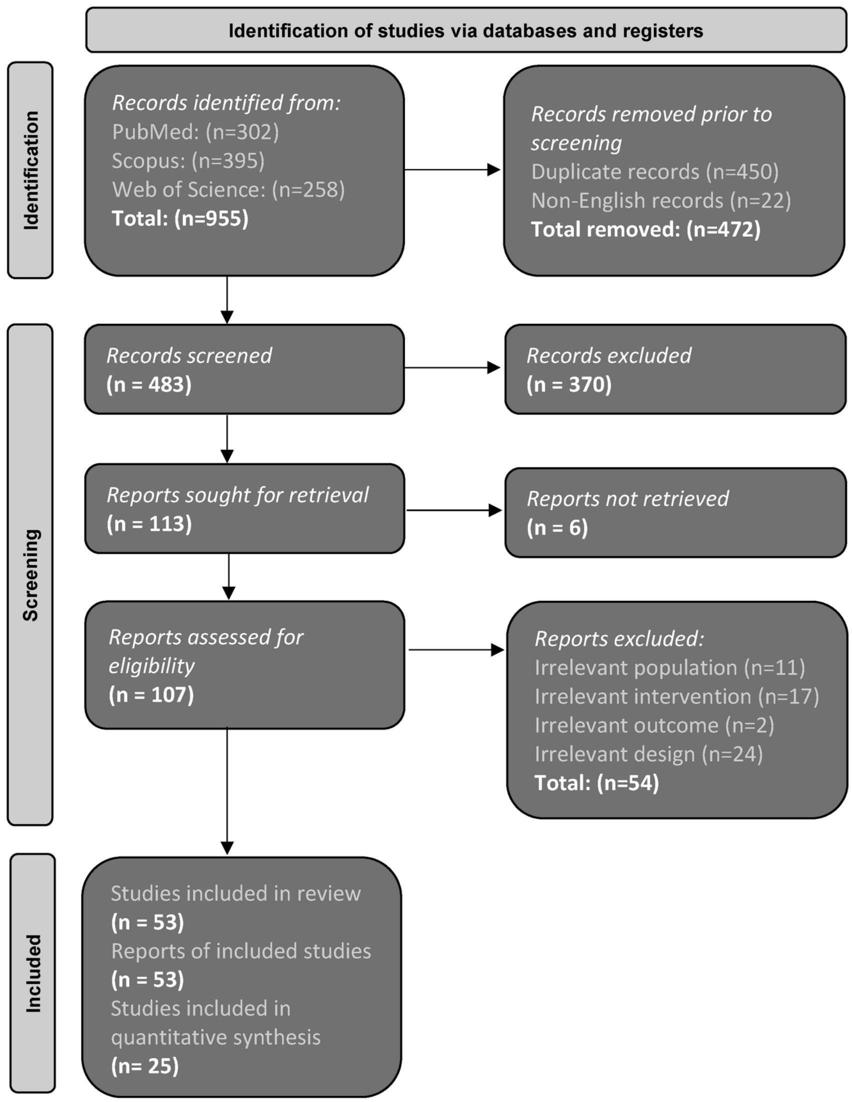

Figure 1: Summary flowchart of the evaluation process of the sought study, according to the PRISMA 2020 Guidelines.

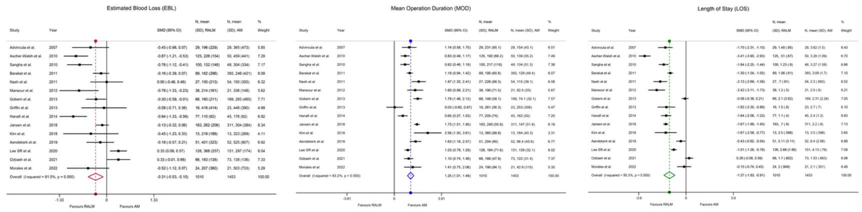

Figure 2: 2a (left): Forest plot comparing RALM to AM on the basis of EBL. 2b (middle): Forest plot comparing RALM to AM on the basis of MOD. 2c (right): Forest plot comparing RALM to AM on the basis of LOS.

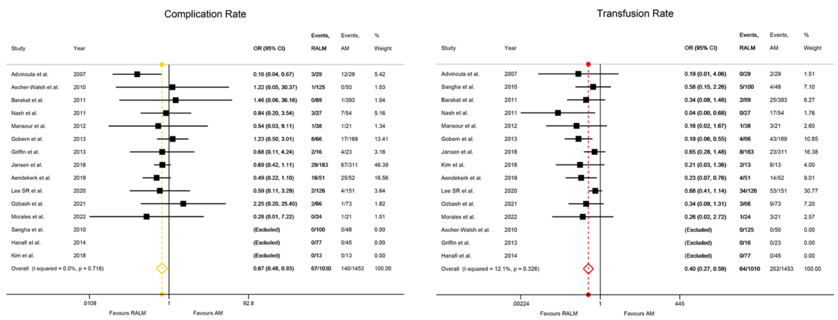

Figure 3: 3a (left): Forest plot comparing RALM to AM on the basis of complication rate. 3b (right): Forest plot comparing RALM to AM on the basis of transfusion rate.

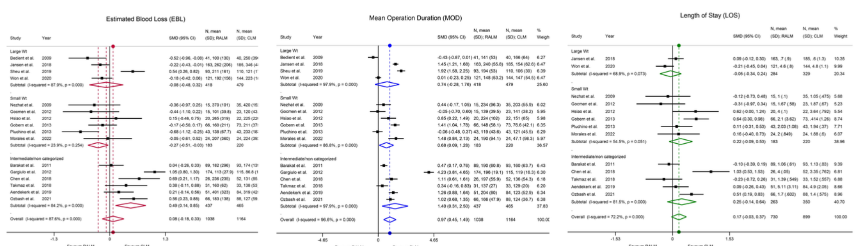

Figure 4: 4a (left): Forest plot comparing RALM to CLM on the basis of EBL. 4b (middle): Forest plot comparing RALM to CLM on the basis of MOD. 4c (right): Forest plot comparing RALM to CLM on the basis of LOS.

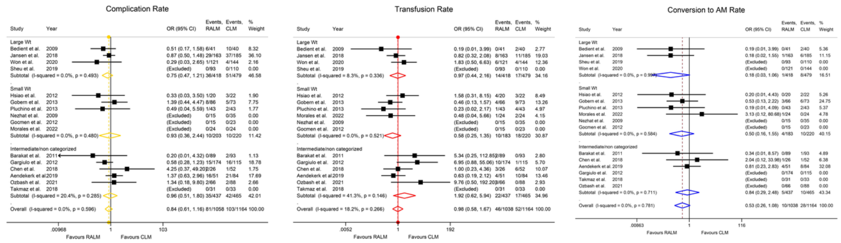

Figure 5: 5a (left): Forest plot comparing RALM to CLM on the basis of complication rate. 5b (middle): Forest plot comparing RALM to CLM on the basis of transfusion rate. 5c (right): Forest plot comparing RALM to CLM on the basis of conversion to laparotomy rate.

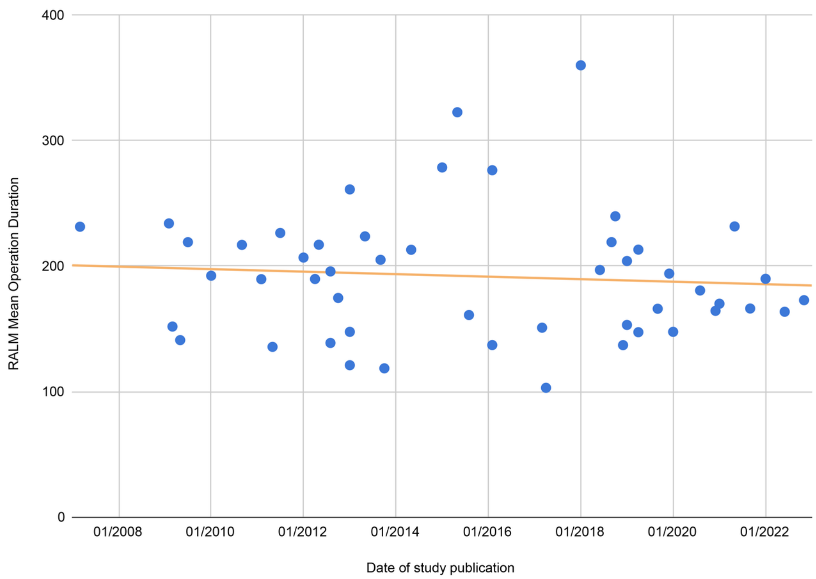

Figure 6: Scatter-plot of the reported RALM MOD of all included studies, with a trend line depicting a downward trend as time passes.

Study	Year	Duration	Patients wishing to concieve	Conception		CPR	Time to conception (mo)	Pregnancy comp/ pathology	Mis/ge	Delivery timing		Delivery mode		LBR	Delivery compl/ons
				Spont	ART					Full term	Pre term	vaginal	CS		
Lonnerfors et al.	2011	04/2006-07/2010	22	18	3	68.2%	10	0	5	10	0	5	5	0.67	0
Cela et al.	2012	06/2007-03/2011	9	7	0	0.78	16	0	0	7	0	2	5	1	0
Pitter et al.	2012	10/2005-11/2010,	NR	77	50	NR	NR	17	24	0	16	2	88	NR	13
Tusheva et al.	2012	01/2006-05/2009	16	12	4	0.5	2023-06-01	0	1	9	2	4	11	93.8%	2
Asmar et al.	2015	01/2011-10/2014	5	2	2	0.8	6	0	1	3	0	0	3	0.25	0
Pitter et al.	2015	08/2005-11/2013	63	17	15	50.8%	8	0	12	NR	NR	NR	NR	NR	NR
Kang et al.	2016	04/2009-10/2013	12	9	0	0.75	NR	0	1	7	0	0	7	1	0
Flyckt et al.	2016	01/1995-12/2009	15	5	3	53.3%	NR	0	0	NR	NR	0	5	1	3
Huberland et al.	2019	07/2009-04/2016	49	20	8	57.1%	17	0	4	21	1	7	17	85.7%	2
Park SU et al.	2020	07/2015-03/2018	15	10	2	0.8	NR	0	1	10	0	0	10	83.3%	1
Goldberg et al.	2021	10/2008-09/2015	63	22	23	71.4%	NR	10	1	33	5	0	29	64.4%	1
Morales et al.	2022	2010-2018	24	5	NR	58.3%	48	NR	1	NR	NR	4	0	0.8	0

Table 1: Fertility and obstetrics outcomes reported by included studies (CPR: clinical pregnancy rate, LBR: live birth rate, CS: caesarean section, NR: not reported).

Study	Publication Year	Recruitment period	Country	Study design	Participants	Patient groups	Comparator	Clinical data	Fertility data
Advincula et al.	2007	2000- 2004	USA	retrospective	58	2	AM	Yes	No
Bedient et al.	2009	2000-2008	USA	retrospective	81	2	CLM	Yes	No
George et al.	2009	2005-2008	USA	retrospective	77	1	N/A	Yes	No
Nezhat et al.	2009	2006 -2007	USA	retrospective	50	2	CLM	Yes	No
Piquion-Joseph et al.	2009	2005-2008	USA	retrospective	18	1	N/A	Yes	No
Ascher-Walsh et al.	2010	2005-2008	USA	retrospective	125	2	AM	Yes	No
Sangha et al.	2010	2005-2009	USA	retrospective	148	2	AM	Yes	No
Barakat et al.	2011	1995-2009	USA	retrospective	575	3	CLM, AM	Yes	No
Nash et al.	2011	2008-2010	USA	retrospective	81	2	AM	Yes	No
Lonnerfors et al.	2011	2006-2010	Sweden	prospective	31	1	N/A	Yes	Yes
Cela et al.	2012	2007-2011	Italy	prospective	48	1	N/A	Yes	Yes
Gargiulo et al.	2012	2007-2009	USA	retrospective	289	2	CLM	Yes	No
Gocmen et al.	2012	2008-2010	Turkey	retrospective	38	2	CLM	Yes	No
Hsiao et al.	2012	2010-2011	Taiwan	retrospective	42	2	CLM	Yes	No
Mansour et al.	2012	2008-2011	Canada	retrospective	59	2	AM	Yes	No
Pitter et al.	2012	2005-2010	USA	retrospective	107	1	N/A	Yes	No
Tan et al.	2012	2009-2011	Taiwan	retrospective	13	1	N/A	Yes	No

Study	Year	Patients	Method	Mean age (±SD)	BMI (±SD)	Parity 0	Parity 1+	CS and/or AS history	Clinical manifestations: Mass	Pain	Bleeding	Infertility	Other	None	Co-morbidities
Advincula et al.	2007	29	RALM	36.6±4.9	25.2±3.9	NR	NR	NR	12	5	15	2	20	0	NR
		29	AM	34.9±4.4	28.3±6.7	NR	NR	NR	7	1	15	9	16	0	NR
Bedient et al.	2009	40	RALM	43±12	24.7±5.0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		41	CLM	40.9±6.6	25.3±5.4	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
George et al.	2009	77	RALM	37.1±5	29.1±6.3	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Nezhat et al.	2009	15	RALM	39±6.3	23.0±3.7	NR	NR	5	NR	NR	NR	NR	NR	NR	NR
		35	CLM	41±6.4	24.0±3.3	NR	NR	15	NR	NR	NR	NR	NR	NR	NR
Piquion-Joseph et al.	2009	18	RALM	36±7	29.0±6.0	NR	NR	4	NR	NR	NR	NR	NR	NR	6
Ascher-Walsh et al.	2010	75	RALM	36.5±7.2	21.7±3.7	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		50	AM	37.2±5.4	20.4±4.1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Sangha et al.	2010	100	RALM	36.2±5.5	29.1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		48	AM	36.4±6.8	29.1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Barakat et al.	2011	89	RALM	37±5.7	25.8±5.3	59	28	28	NR	NR	NR	NR	NR	NR	NR
		93	CLM	38.2±1.8	25.1±6.0	51	41	59	NR	NR	NR	NR	NR	NR	NR
		393	AM	37±1.4	28.2±7.5	243	187	132	NR	NR	NR	NR	NR	NR	NR
Nash et al.	2011	27	RALM	38.3±6.3	25.0±4.8	NR	NR	NR	0	21	14	0	8	0	NR
		54	AM	35.8±5.5	26.5±6.2	NR	NR	NR	0	31	40	0	7	0	NR
Lonnerfors et al.	2011	31	RALM	35± 3.4	22.1±1.1	21	10	NR	NR	NR	NR	14	NR	NR	NR
Cela et al.	2012	48	RALM	35.2± 6.0	23.5±4.1	31	17	NR	NR	NR	NR	NR	NR	NR	NR
Gargiulo et al.	2012	174	RALM	37.8±6.5	25.9±6.4	NR	NR	10	NR	NR	NR	NR	NR	NR	NR
		115	CLM	39.2±5.7	26.2±7.3	NR	NR	10	NR	NR	NR	NR	NR	NR	NR
Goçmen et al.	2012	15	RALM	34.2±5.7	25.6 ±3.3	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		33	CLM	35.7±6.1	27.6±5.[illegible]	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Study	Year	Patients	Da Vinci System	Camera port (mm)	Robotic ports (mm)	Accessory port(s) (mm)	MMN	MMD	LMMD	MMW
Advincula et al.	2007	29	Si	12	8.8	12	NR	NR	NR	227.86±247.54
Bedient et al.	2009	41	Standard or S	NR	NR	NR	2.7±1.9	NR	NR	210+-270
George et al.	2009	77	Standard	NR	NR	NR	NR	NR	NR	270.42±199.35
Nezhat et al.	2009	15	Standard	12	8.8	5 or 12	3.0±1.7	NR	5.1±1.3	116±93.42
Piquion-Joseph et al.	2009	18	Standard	12	88,(8)	12	NR	NR	NR	NR
Ascher-Walsh et al.	2010	125	Si	12	8.8	12	2.4±1.5	NR	NR	321.16±243.87
Sangha et al.	2010	100	Standard	12	8.8	5 or 10	3.0±3.8	NR	7.85±3.45	NR
Barakat et al.	2011	89	Si	12	888	10	2.9±1.7	7.9±3.0	NR	270.3±245.2
Nash et al.	2011	27	Standard	NR	NR	NR	NR	NR	NR	NR
Lonnerfors et al.	2011	31	Si	12	888	12 or 15	1.5±1.0	7.12±1.7	NR	NR
Cela et al.	2012	48	Si	12	8.8	12	1.5±1.4	6.7±1.9	NR	NR
Gargiulo et al.	2012	174	Standard	12	88,(8)	12	3.4±2.8	NR	NR	177.11±143.6
Gocmen et al.	2012	15	S	12	8.8	12	2.73 ± 3.1	NR	6.0 ± 1.5	NR
Hsiao et al.	2012	20	Si	12	8.8	10	2.36±2.4	NR	6.41±1.52	139.3±145.2
Mansour et al.	2012	38	Standard	12	8.8	12 or 15	2.0 ± 1.4	NR	9.1 ± 2.0	389.0 ± 170.4
Pitter et al.	2012	108	Standard	NR	NR	NR	3.9±3.2	NR	7.5±3.0	191.7±144.8
Tan et al.	2012	13	Standard	NR	NR	NR	NR	NR	NR	119.6 66.2
Tusheva et al.	2012	30	S	12	7.7	8 and/or 5	2.24±0.98	NR	7.21±3.7	NR
Gobern et al.	2013	66	Standard	NR	NR	NR	NR	NR	6.9±3.54	179.6±197.1
Griffin et al.	2013	16	Standard	NR	NR	NR	2.8±1.9	NR	NR	318.6±154
Pluchino et al.	2013	43	Si	12	8.8	10	1.97±1.48	4.76±1.71	NR	117.8±30.05
Goetgheluck et al.	2014	18	Si	12	8.8	12	1.34±0.58	7.7±2.74	NR	149.7±77.7
Hanafi et al.	2014	77	S	12	8.8	12	3.1±1.4	4.3±1.79	NR	NR