Simple radiologic assessment of visceral obesity and prediction of surgical morbidity in high-risk endometrial cancer: a reliability and accuracy pilot study

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Abstract

Objective: To evaluate the reliability of sagittal abdominal diameter (SAD)—a surrogate of visceral obesity—in MRI, and its accuracy to predict the surgical morbidity of aortic lymphadenectomy. **Design**: A multicentre reliability (phase 1) and accuracy (phase 2) cohort study. **Setting**: Three Spanish referral hospitals. **Population**: High-risk endometrial cancer patients undergoing minimally invasive surgical staging. Patients were classified into subgroups: conventional vs. robotic-assisted laparoscopy, and transperitoneal vs. extraperitoneal technique. **Methods**: Retrospective analysis of data from the STELLA-2 randomized controlled trial. In the first phase, we measured the agreement of three SAD measurements (at the umbilicus, the renal vein, and the inferior mesenteric artery) and selected the most reliable one. In phase two, we evaluated the diagnostic accuracy of SAD to predict surgical morbidity. **Main Outcome Measures**: surgical morbidity was defined by a core outcome set including variables related to blood loss, operative time, surgical complications, and para-aortic lymphadenectomy difficulty. **Results**: In phase one, all measurements showed good inter-rater and intra-rater agreement. Umbilical SAD was the most reliable one. In phase two, we included 136 patients. Umbilical SAD had a good diagnostic accuracy to predict surgical morbidity in patients undergoing transperitoneal laparoscopic lymphadenectomy (0.73 in ROC curve). It performed better than BMI and other anthropometric measurements. We calculated a cut-off point of 246 mm (sensitivity: 0.56 and specificity: 0.80). **Conclusions**: Umbilical SAD is a simple, reliable, and potentially useful measurement to predict surgical morbidity in endometrial cancer patients undergoing minimally invasive surgical staging, especially when facing transperitoneal aortic lymphadenectomy.

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ABSTRACT

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Design: A multicentre reliability (phase 1) and accuracy (phase 2) cohort study.

Setting: Three Spanish referral hospitals.

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Main Outcome Measures: surgical morbidity was defined by a core outcome set including variables related to blood loss, operative time, surgical complications, and para-aortic lymphadenectomy difficulty.

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Conclusions : Umbilical SAD is a simple, reliable, and potentially useful measurement to predict surgical morbidity in endometrial cancer patients undergoing minimally invasive surgical staging, especially when facing transperitoneal aortic lymphadenectomy.

Keywords: surgical morbidity, minimally invasive surgery, para-aortic lymphadenectomy, visceral obesity

TWEETABLE ABSTRACT

Measuring visceral obesity may predict the morbidity of aortic lymphadenectomy in endometrial cancer patients

INTRODUCTION

Current guidelines recommend that patients with high-risk endometrial cancer undergo comprehensive surgical staging including the evaluation of aortic nodes [1,2]. But surgical staging is still controversial [3]. Minimally invasive surgery has long ago proved its well-known benefits, and more recent techniques have enhanced the options available. Laparoscopic para-aortic lymphadenectomy can be performed in four different ways using conventional or robotic-assisted laparoscopy, and the transperitoneal or extraperitoneal approach. The procedure is generally safe, but each technique and approach has its advantages and disadvantages. Although solid evidence is lacking, it appears that the extraperitoneal technique and robotic assistance are associated with less surgical morbidity[4,5]. But aortic evaluation is not without risks: morbidity rates can rise beyond 50% [6].

The prediction of surgical morbidity is fundamental in gynaecological oncology [6–10]. One of the key factors associated with surgical morbidity is obesity [11–13]. Patients with endometrial cancer are usually overweight, and a lot of them have abdominal or visceral obesity, defined as an excess of intra-abdominal fat [14]. Some studies have shown a direct association between visceral obesity and surgical morbidity[15–18]. But only one was conducted in endometrial cancer patients [19].

Intra-abdominal fat can be evaluated by many anthropometric measurements (e.g. waist circumference, waist-hip ratio, visceral fat area, and sagittal abdominal diameter). Sagittal abdominal diameter (SAD) has been demonstrated to be the best surrogate of intra-abdominal fat[20]. It can be measured using the Holtain Kahn callipers in the office, but this can be a difficult task on obese patients. SAD and intra-abdominal fat can also be measured by several imaging methods (dual-energy X-ray absorptiometry, magnetic resonance [MRI], and computed tomography [CT]), but its measurement has not been standardized [21].

The current tools available to preoperatively assess surgical morbidity are limited. We lack a "one-size-fits-all" measurement since surgical outcomes depend on the technique, the approach, and each specific procedure. Moreover, the evaluation of obesity in gynaecological oncology is scarce, and most studies focus only on body mass index (BMI)—a widespread but limited measurement [22].

We asked whether the measurement of SAD in MRI is reliable and useful to predict surgical morbidity in high-risk endometrial cancer patients undergoing minimally invasive aortic lymphadenectomy. This is the first study to evaluate this measurement as a method to predict surgical morbidity in endometrial cancer patients.

METHODS

Study design

We conducted a retrospective analysis of prospectively collected data from the STELLA-2 randomized controlled trial [23]. The analysis was completed in two phases. In the first phase, we measured the agreement of sagittal abdominal diameter (SAD) and then selected the most reliable measurement. In the second phase, we evaluated its diagnostic accuracy to assess surgical morbidity (Figure 1).

Patients were not involved in the study design (only participating as study subjects). The study was carried out in three Spanish referral hospitals: Vall d'Hebron Barcelona Hospital Campus, Hospital Universitario La Paz, and Hospital General de Valencia. The study was approved by the Ethics Committee of Hospital Vall d'Hebron (protocol PR(AMI)168/2015) and by the institutional review boards of the participating hospitals.

The Guidelines for Reporting Reliability and Agreement Studies (GRRAS) and the Standards for Reporting Diagnostic accuracy studies (STARD-2015) were followed in compliance with the Equator Network recommendations. The present study did not receive any funding.

Subjects

Between 2012 and 2019, 209 patients were enrolled in the STELLA-2 trial, a randomized multicentre prospective trial comparing the transperitoneal and extraperitoneal technique for laparoscopic para-aortic lymphadenectomy in endometrial and early ovarian cancer[23]. All the subjects for the present study were selected from that trial.

For phase one, we randomly selected a group of patients with endometrial cancer to evaluate SAD in MRI images (Group 1). The sample size for this group was calculated to detect a minimum correlation coefficient of 0.8, with an α risk of 0.05 and a β risk of 0.05, in a two-sided test.

For phase two we included all patients from the STELLA-2 trial with high-risk endometrial cancer who underwent comprehensive surgical staging by minimally invasive surgery (Group 2). High-risk was defined in the original trial as the presence of any of the following: deep myometrial invasion ([?]50% as elicited by MRI and/or transvaginal ultrasound) or stromal cervical involvement, grade 3 endometrial tumours, or non-endometrioid tumours [23]. Patients with missing data were excluded. They were divided into subgroups according to the para-aortic lymphadenectomy technique and the minimally invasive approach (Figure 1).

The surgical procedures performed have been previously described[24].

Measurements

Phase 1

Preoperative MRI was performed following the European Society of Gynaecological Oncology (ESGO) and the Spanish society (SEGO) guidelines, obtaining T1 and T2-weighted 5 mm axial images of the abdomen and pelvis.

SAD was measured on axial MRI images using the local software available. Measurements were made manually using the digital callipers in millimetres (mm).

We defined three anatomical references for SAD measurement (Figure 2a). Umbilical SAD had been previously described [25]. We chose the left renal vein as a new anatomical landmark since it's the superior limit of the para-aortic lymph node dissection[3]. During this procedure, the inferior mesenteric artery must also be carefully dissected, so we selected this as another point of reference. In our experience, these two sites reflect the areas where the procedure is most challenging and where we encounter the most complications. Two observers were selected to carry out the SAD measurements: an experienced radiologist (observer A) and an obstetrics and gynaecology first-year resident (observer B). They received written instructions and made two measurements of the three diameters, two weeks apart.

For inter-rater agreement, we evaluated the concordance between the two observers' measurements, whereas for the intra-rater agreement we compared their first measurements with the ones carried out two weeks later (Figure 1).

Phase 2

For the second phase, the primary end-point (surgical morbidity) was a core outcome set defined as the presence of any of the following criteria: 1) need for blood transfusion, 2) Haematocrit drop > 90th percentile (>11.8% in our cohort), 3) Total operative time >90th percentile (>350 min in our cohort), 4) laparoscopic para-aortic lymphadenectomy operative time >90th percentile (>135 min in our cohort), 5) Intraoperative surgical complications [?] grade III[26] or during para-aortic lymphadenectomy, 6) Postoperative surgical complications [?] grade III [27] or related to para-aortic lymphadenectomy, 7) uncompleted or converted laparoscopic para-aortic lymphadenectomy (Table S1).

SAD was measured preoperatively, so observers were unaware of the outcomes. We performed a multivariate logistic regression analysis including the following covariates: anthropometric measurements (SAD, BMI, waist-hip ratio, waist circumference), age-adjusted comorbidity index [28], tumour characteristics, patients' age, and previous surgeries.

The diagnostic accuracy of SAD to predict surgical morbidity was measured using ROC curves in Group 2 and all subgroups. If the discriminatory power was adequate, we estimated the optimal cut-off point (the closest point to the top left corner in the ROC curve) and calculated sensitivity and specificity, as well as negative and positive predictive values (NPV and PPV). We also compared the diagnostic accuracy of SAD with other anthropometric measurements.

Data analysis

In phase one, we calculated Pearson's correlation coefficient (r) and traced concordance scatter plots. The agreement was evaluated by Bland Altman plots [29] and the concordance correlation coefficient for repeated measurements (ρ_c)[30].

For phase two, a logistic regression analysis was modelled for the composite outcome and the covariates. DeLong's test was used to compare two correlated ROC curves. We computed the area under the curve (AUC) confidence intervals (95% CI) and considered a clinically appropriate diagnostic power if AUC was greater than 0.70.

Statistical analysis was carried out using Stata software v13.1 (StataCorp LLC, College Station, TX, USA), R software v. 4.0 (R Core Team, GNU), and Wizard - Statistics & Analysis v.1.9 (©Evan Miller). Statistical significance was defined if p <0.05.

RESULTS

Phase one: Reliability assessment

We analysed the measurements from 15 patients (Group 1), including 30 observations for inter-rater variability and another 30 for intra-rater variability (Figure 1). The measurements from all three anatomical locations showed good correlation, agreement, and concordance.

Inter-rater agreement

We found a strong linear correlation between the two observers for all three readings (Figure 2b), and SAD at the umbilicus showed the best inter-rater concordance (ρ_c = 0.96, 95% CI 0.94–0.98) (Table S2). Bland-Altman plots also show that umbilical SAD had the best agreement (Figure 2c).

Intra-rater agreement

The first and second measurements of the observers were nearly identical. There was a strong linear correlation for all three measurements ($r > 0.98$). Concordance and Bland-Altman plots revealed a high agreement for all sagittal abdominal diameters (ρ_c>0.98) (Table S3).

Given the superior reliability of umbilical SAD, we tested its diagnostic accuracy to predict surgical morbidity in group 2.

Phase two: Evaluation of diagnostic accuracy and subgroup analysis

Thirty-five patients (20.4%) were excluded because of missing data. A total of 136 patients was analysed (Figure 1).

We found that umbilical SAD (u-SAD) was normally distributed in our sample (mean 239 ± 40 mm SD) (Table 1). Patients who encountered surgical morbidity had a significantly higher u-SAD compared with those without surgical morbidity (mean 243 ± 39 mm vs. 230 ± 36 mm,p =0.03).

In the univariate analysis, only the waist-hip ratio (WHR) and u-SAD showed a significant association with the main outcome measure (p <0.05). Despite these findings, when we assessed their diagnostic accuracy as a single measurement, neither of them proved to be clinically useful to predict surgical morbidity (AUC<0.70).

We found that nearly half of intraoperative complications occurred during the para-aortic lymph node dissection (6/14). A higher measurement of u-SAD was significantly associated with an incomplete lymphadenectomy (p <0.001). We also found a strong positive correlation between the conversion rate and the u-SAD measurement, although this was not statistically significant (Figure S1). The rest of the surgical morbidity variables were not independently associated with the u-SAD measurement.

The vast majority of patients in group 2 (Table S4) underwent a hysterectomy, bilateral salpingo-oophorectomy, pelvic and para-aortic lymphadenectomy (85.3%); only eight patients underwent exclusively para-aortic lymphadenectomy. The most frequent histopathology was endometrioid (53.7%) followed by

serous (21.3%) neoplasia. Previous surgery, either open or laparoscopic, was not associated with the primary end-point. The median follow-up was 31 months (IQR 15–52).

We observed 17 deaths, but only two of them were grade V operative complications (both within 30 days of the surgery). One of them was directly associated with the procedure (bowel perforation), and the other one was a patient who suffered a stroke 5 days after surgery. Thirteen patients died from disease progression and the remaining three from other metastatic malignancies (breast cancer and multiple endocrine neoplasia).

Subgroup analysis

All subgroups were uniformly distributed (Figure 1), even though patients were originally randomized only to the para-aortic lymphadenectomy technique.

Intraoperative complications were more frequent in the transperitoneal vs. extraperitoneal subgroup (9 vs. 5), but this difference was not statistically significant (p =0.173). We found a significant negative correlation between u-SAD and aortic lymph node yield in the transperitoneal group (p <0.001), but no correlation was observed in the extraperitoneal subgroup (p =0.115) (Figure S2).

In the transperitoneal subgroup, BMI and u-SAD showed a significant independent association with the primary end-point (p <0.05). In this same subgroup, u-SAD was significantly higher in patients who encountered surgical morbidity (Figure 3a). In contrast, in the extraperitoneal subgroup, the main outcome was independent of the u-SAD measurement (Figure 3b).

We compared the diagnostic accuracy of u-SAD with the other anthropometric measurements of obesity in the transperitoneal subgroup, and u-SAD outperformed the others (Figure 3c). The discriminatory power was good in the transperitoneal subgroup, but poor in the extraperitoneal one (Figure 3d). In the subgroup of patients who underwent transperitoneal para-aortic lymphadenectomy by conventional laparoscopy, the diagnostic accuracy was higher (n=34, AUC=0.78).

In patients who underwent staging by the extraperitoneal technique, surgical morbidity was more frequently observed in those operated by conventional vs. robotic-assisted laparoscopy (52.6% vs. 28%,p =0.05) (Table S4).

Optimal cut-off point estimation

For patients undergoing para-aortic lymphadenectomy by the transperitoneal technique, we determined that 246 mm was the optimal cut-off point for u-SAD as a predictor of surgical morbidity. Using this value, the sensitivity and specificity were 0.56 and 0.80 respectively (NPV 0.69, PPV 0.70).

DISCUSSION

Main findings

We found that sagittal abdominal diameter (SAD) measured in MRI (especially at the umbilicus) is a reliable method to evaluate intra-abdominal fat in endometrial cancer patients. Umbilical SAD (u-SAD) has an acceptable diagnostic accuracy to predict surgical morbidity in patients undergoing transperitoneal minimally invasive aortic lymphadenectomy, especially using conventional laparoscopy. In our cohort, a patient undergoing a transperitoneal aortic lymphadenectomy with a u-SAD greater than 246 mm would have a probability of 69% of encountering surgical morbidity (positive likelihood ratio=2.8). Those having less than 246 mm had significantly less risk (probability of 31%, negative likelihood ratio=0.55). But its applicability in all patients with endometrial cancer undergoing surgical staging is limited.

U-SAD seems to have a better diagnostic performance than BMI—the most commonly used obesity measurement. Indeed, BMI use is widespread, but its clinical use as a tool to predict morbidity is questionable[15,16,31,32]. More than obesity alone, visceral obesity has been associated with worse surgical outcomes[15–19].

Endometrial cancer patients with abdominal obesity have more visceral fat in areas where the staging surgery is already challenging, particularly during the lymph node dissection. Thus, having more intra-abdominal fat could yield fewer aortic nodes. We found that, in the transperitoneal subgroup, for every additional centimetre in u-SAD the lymphadenectomy obtained one aortic lymph node less (Figure S2). By contrast, aortic node count was independent of u-SAD in the extraperitoneal subgroup, supporting the benefit of this technique that bypasses the intra-abdominal space.

A previous study demonstrated that SAD measured in CT-scans or MRI was superior to BMI when used to predict surgical difficulty[33]. Our results are in line with these findings (Figures 3c, S1, S2), but in that study, only 49% of patients underwent laparoscopy aortic lymphadenectomy, and they enrolled more obese patients compared with our cohort (median BMI: 37 vs. 29 kg/m^2, median SAD: 300 vs. 235 mm).

Another study found that higher intra-abdominal fat was associated with worse surgical outcomes and more conversions [19]. We also found that an increasing u-SAD was associated with a higher conversion rate (Figure S1), especially in the transperitoneal subgroup.

Surgical morbidity is critical in gynaecologic oncology because it may delay oncologic treatment, substantially increase costs of care, and worsen patients' survival and quality of life [34,35]. Thus, efforts should focus on establishing a method to preoperatively identify those patients at risk. Several authors have attempted to describe predictors of complications and to validate risk scoring systems specifically in gynaecologic oncology surgery[6–10,34,36–39]. But the studied populations were too heterogeneous, and yielded poor results, hindering their clinical application. It is difficult to establish a single scoring system valid for all gynaecological malignancies, given the complexity of diseases, treatments, and patients.

Our surgical morbidity results are comparable to the outcomes of large cohorts and a recent meta-analysis [39–41]. We observed an intraoperative complication rate of 10.3% and an early postoperative complication rate of 26.5%. We found a higher rate of surgical morbidity in the conventional vs. robotic-assisted laparoscopy subgroup, findings that are consistent with previously reported results[4,5,24,42].

Although our findings are similar to other published studies, we cannot compare our main outcome measure since it has not been previously described.

Measuring surgical morbidity is challenging. So far, studies that evaluate the prediction of surgical morbidity have used different outcome measures, but they fail to address specific issues related to the surgical procedure. Thus, we defined a novel core outcome set that identifies the morbidity specifically associated with the laparoscopic aortic lymphadenectomy. Similar core outcome sets have been described in other areas [43], but they are lacking in gynaecologic oncology.

Previously published risk prediction models have performed worse than ours, having a diagnostic power insufficient for clinical use (< 0.70) [7,8].

Very few studies that evaluate surgical morbidity prediction have included the surgical approach in their models (i.e. minimally invasive vs. open), and none of them has considered the surgical technique for para-aortic lymphadenectomy (transperitoneal vs. extraperitoneal).

According to current evidence, both techniques seem to be equivalent. But one meta-analysis suggested that intraoperative complications are more frequent with the transperitoneal technique [4]. We found similar results: 14.1% vs. 6.9% in the transperitoneal vs. extraperitoneal subgroups (p =0.08). Surgical morbidity was similar in these groups, but we found that u-SAD measurement was a more powerful predictor in the transperitoneal subgroup (Figure 3d). We believe this difference is due to the challenges of the transperitoneal technique, where surgeons must overcome the intra-abdominal fat during the entire procedure.

Strengths and Limitations

The main strength of our study is that it is the first one to assess the usefulness of SAD as a predictive tool for surgical morbidity. Few studies examine the role of a minimally invasive approach and the aortic lymphadenectomy technique in surgical morbidity, our study sheds light in this regard.

We believe u-SAD could have clinical applicability because of two reasons: preoperative imaging use is widespread, and u-SAD is reliable, straightforward, and easy to measure.

Also, this measurement is not limited to MRI, it has been described in CT-scans [33].

Research results in surgery are subject to several biases: surgeon volume, experience, and procedure complexity. In our study, these biases were mitigated because the surgeries were carried out in three referral hospitals, by a small group of expert oncologic surgeons; and most patients had the same diagnosis and underwent the same procedure. Since data were collected prospectively, this prevented observer and recall bias. The long-term follow-up helped to reduce underreporting, and the precise measuring of variables (e.g. haematocrit drop instead of estimated blood loss) reduced measurement error or estimator bias.

The major limitation of our study is the lack of validation of the core outcome set. Some variables were defined as percentiles (Table S1), so they are affected by the surgical results of each centre. This requires everyone to determine their cut-off point.

We did not include lymph node count in the composite outcome measure (but it was recorded and analysed), as we found in a previous study that all minimally invasive techniques yielded the same number of aortic nodes [24]. Instead, we estimated surgical difficulty by accounting for the completion of the aortic lymphadenectomy.

We did not calculate the sample size for the second phase, and given the limited number of patients, some differences were not statistically significant.

Interpretation

Globally, a lot of minimally invasive surgeons still prefer the transperitoneal approach since the anatomical landmarks are similar to laparotomy, and there's more experience in performing other gynaecological procedures using this approach.

The treatment of endometrial cancer is still heterogeneous around the world, and outcomes vary greatly. The incidence of endometrial cancer is escalating due to the global obesity epidemic. Thus, surgical morbidity will thrive. Surgeons should focus on both oncologic results (e.g. survival) and surgical morbidity.

Personalised medicine is becoming the standard of care, so we need the necessary tools in gynaecologic oncology to offer each woman with endometrial cancer the best treatment option. Applying the same surgery to all patients is obsolescent; each individual is different, with different types of obesity, and different risks. We believe umbilical SAD could be included in the preoperative assessment of endometrial cancer patients undergoing minimally invasive para-aortic lymphadenectomy. It could help surgeons and patients choose the safest option, and decide whether or not the transperitoneal approach is suitable.

CONCLUSION

Sagittal abdominal diameter is a simple and potentially useful measurement to preoperatively assess the surgical risk of endometrial cancer patients undergoing minimally invasive aortic lymphadenectomy. Our core outcome set should be validated, and the usefulness of SAD must be assessed in larger cohorts.

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Disclosure of interests

All authors declare they have no conflicts of interest.

Contribution to Authorship

ACP was involved in the conception, design, and data analysis of the study, as well as drafting and writing the manuscript; VGO co-led the preparation of the article, provided oversight on the study design, participated

in the data analysis and interpretation of results, and evaluated the manuscript; AHG and JGE helped to collect the data; BDF and AGM helped to collect the data, supervised the development of the work, and were involved in the conception of the study and the manuscript evaluation. All the authors participated in the final revision of the manuscript which was unanimously approved for publication.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

REFERENCES

1. Bogani G, Murgia F, Ditto A, Raspagliesi F. Sentinel node mapping vs. lymphadenectomy in endometrial cancer: A systematic review and meta-analysis. Gynecol Oncol. 2019;153(3):676–83.

2. Pölcher M, Rottmann M, Brugger S, Mahner S, Dannecker C, Kiechle M, et al. Lymph node dissection in endometrial cancer and clinical outcome: A population-based study in 5546 patients. Gynecol Oncol. 2019;154(1):65–71.

3. Colombo N, Creutzberg C, Amant F, Bosse T, Gonzalez-Martin A, Ledermann J, et al. ESMO-ESGO-ESTRO Consensus Conference on Endometrial Cancer: Diagnosis, Treatment and Follow-up. Int J Gynecol Cancer. 2016;26(1):2–30.

4. Prodromidou A, Machairas N, Spartalis E, Kostakis ID, Iavazzo C, Moris D, et al. Transperitoneal Versus Extraperitoneal Laparoscopic Lymphadenectomy for Gynecological Malignancies: A Systematic Review and Meta-analysis. Anticancer Res. 2018;38(8):4677–81.

5. Ind T, Laios A, Hacking M, Nobbenhuis M. A comparison of operative outcomes between standard and robotic laparoscopic surgery for endometrial cancer: A systematic review and meta-analysis. Int J Med Robot. 2017;13(4):e1851.

6. Kuroda K, Yamamoto Y, Yanagisawa M, Kawata A, Akiba N, Suzuki K, et al. Risk factors and a prediction model for lower limb lymphedema following lymphadenectomy in gynecologic cancer: A hospital-based retrospective cohort study. BMC Womens Health. 2017;17(1):50.

7. Kondalsamy-Chennakesavan S, Janda M, Gebski V, Baker J, Brand A, Hogg R, et al. Risk factors to predict the incidence of surgical adverse events following open or laparoscopic surgery for apparent early stage endometrial cancer: Results from a randomised controlled trial. Eur J Cancer. 2012;48(14):2155–62.

8. Shim SH, Lee SJ, Dong M, Suh JH, Kim SY, Lee JH, et al. Prediction model for 30-day morbidity after gynecological malignancy surgery. PLoS One. 2017;12(6):e0178610.

9. Bakkum-Gamez JN, Dowdy SC, Borah BJ, Haas LR, Mariani A, Martin JR, et al. Predictors and costs of surgical site infections in patients with endometrial cancer. Gynecol Oncol. 2013;130(1):100–6.

10. Gerestein CG, Nieuwenhuyzen-de Boer GM, Eijkemans MJ, Kooi GS, Burger CW. Prediction of 30-day morbidity after primary cytoreductive surgery for advanced stage ovarian cancer. Eur J Cancer. 2010;46(1):102–9.

11. Giugale LE, Di Santo N, Smolkin ME, Havrilesky LJ, Modesitt SC. Beyond mere obesity: Effect of increasing obesity classifications on hysterectomy outcomes for uterine cancer/hyperplasia. Gynecol Oncol. 2012;127(2):326–31.

12. Orekoya O, Samson ME, Trivedi T, Vyas S, Steck SE. The Impact of Obesity on Surgical Outcome in Endometrial Cancer Patients: A Systematic Review. J Gynecol Surg. 2016;32(3):149–57.

13. Uccella S, Bonzini M, Palomba S, Fanfani F, Ceccaroni M, Seracchioli R, et al. Impact of Obesity on Surgical Treatment for Endometrial Cancer: A Multicenter Study Comparing Laparoscopy vs Open Surgery, with Propensity-Matched Analysis. J Minim Invasive Gynecol. 2016;23(1):53–61.

14. Aune D, Navarro Rosenblatt DA, Chan DSM, Vingeliene S, Abar L, Vieira AR, et al. Anthropometric factors and endometrial cancer risk: A systematic review and dose-response meta-analysis of prospective studies. Ann Oncol. 2015;26(8):1635–48.

15. Seki Y, Ohue M, Sekimoto M, Takiguchi S, Takemasa I, Ikeda M, et al. Evaluation of the technical difficulty performing laparoscopic resection of a rectosigmoid carcinoma: visceral fat reflects technical difficulty more accurately than body mass index. Surg Endosc. 2007;21(6):929–34.

16. Kang J, Baek S-E, Kim T, Hur H, Min BS, Lim JS, et al. Impact of fat obesity on laparoscopic total mesorectal excision: more reliable indicator than body mass index. Int J Colorectal Dis. 2012;27(4):497–505.

17. Watanabe J, Tatsumi K, Ota M, Suwa Y, Suzuki S, Watanabe A, et al. The impact of visceral obesity on surgical outcomes of laparoscopic surgery for colon cancer. Int J Colorectal Dis. 2014;29(3):343–51.

18. Ballian N, Lubner MG, Munoz A, Harms BA, Heise CP, Foley EF, et al. Visceral obesity is associated with outcomes of total mesorectal excision for rectal adenocarcinoma. J Surg Oncol. 2012;105(4):365–70.

19. Palomba S, Zupi E, Russo T, Oppedisano R, Manguso F, Falbo A, et al. Presurgical assessment of intraabdominal visceral fat in obese patients with early-stage endometrial cancer treated with laparoscopic approach: Relationships with early laparotomic conversions. J Minim Invasive Gynecol. 2007;14(2):195–201.

20. Zamboni M, Turcato E, Armellini F, Kahn H, Zivelonghi A, Santana H, et al. Sagittal abdominal diameter as a practical predictor of visceral fat. Int J Obes. 1998;22(7):655–60.

21. Molokhia AA. Waist circumference is better than body mass index, but sagittal anterior diameter may be even better. Br J Anaesth. 2017;118(2):274.

22. Biswas N, Hogston P. Surgical risk from obesity in gynaecology. Obstet Gynaecol. 2011;13(2):87–91.

23. Díaz-Feijoo B, Bebia V, Hernández A, Gilabert-Estalles J, Franco-Camps S, de la Torre J, et al. Surgical complications comparing extraperitoneal vs transperitoneal laparoscopic aortic staging in early stage ovarian and endometrial cancer. Gynecol Oncol. 2021;160(1):83-90.

24. Díaz-Feijoo B, Correa-Paris A, Pérez-Benavente A, Franco-Camps S, Sánchez-Iglesias JL, Cabrera S, et al. Prospective Randomized Trial Comparing Transperitoneal Versus Extraperitoneal Laparoscopic Aortic Lymphadenectomy for Surgical Staging of Endometrial and Ovarian Cancer: The STELLA Trial. Ann Surg Oncol. 2016;23(9):2966–74.

25. Yim JY, Kim D, Lim SH, Park MJ, Choi SH, Lee CH, et al. Sagittal Abdominal Diameter Is a Strong Anthropometric Measure of Visceral Adipose Tissue in the Asian General Population. Diabetes Care. 2010;33(12):2665–70.

26. Dell-Kuster S, Gomes N V., Gawria L, Aghlmandi S, Aduse-Poku M, Bissett I, et al. Prospective validation of classification of intraoperative adverse events (ClassIntra): international, multicentre cohort study. BMJ. 2020;370:1–11.

27. Dindo D, Demartines N, Clavien P-A. Classification of Surgical Complications. Ann Surg. 2004;240(2):205–13.

28. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. J Clin Epidemiol. 1994;47(11):1245–51.

29. Bland JM, Altman DG. Measuring agreement in method comparison studies. Stat Methods Med Res. 1999;8(2):135–60.

30. Chinchilli VM, Martel JK, Kumanyika S, Lloyd T. A Weighted Concordance Correlation Coefficient for Repeated Measurement Designs. Biometrics. 1996;52(1):341.

31. Salman MC, Usubutun A, Ozlu T, Boynukalin K, Yuce K. Obesity does not affect the number of retrieved lymph nodes and the rate of intraoperative complications in gynecologic cancers. J Gynecol Oncol. 2010;21(1):24.

32. Helm CW, Arumugam C, Gordinier ME, Metzinger DS, Pan J, Rai SN. Laparoscopic surgery for endometrial cancer: increasing body mass index does not impact postoperative complications. J Gynecol Oncol. 2011;22(3):168.

33. Harrison RF, Mcnamara JE, Beaumont CB, Sadowski EA, Chappell RJ, Shahzad MM, et al. Using simple radiologic measurements to anticipate surgical challenge in endometrial cancer: a prospective study. Int J Gynecol Cancer. 2019;29(1):102–7.

34. Dowdy SC, Borah BJ, Bakkum-Gamez JN, Weaver AL, McGree ME, Haas LR, et al. Prospective assessment of survival, morbidity, and cost associated with lymphadenectomy in low-risk endometrial cancer. Gynecol Oncol. 2012;127(1):5–10.

35. Doll KM, Barber EL, Bensen JT, Revilla MC, Snavely AC, Bennett A V., et al. The impact of surgical complications on health-related quality of life in women undergoing gynecologic and gynecologic oncology procedures: a prospective longitudinal cohort study. Am J Obstet Gynecol. 2016;215(4):457.e1-457.e13.

36. Clark RM, Lee MS, Alejandro Rauh-Hain J, Hall T, Boruta DM, del Carmen MG, et al. Surgical Apgar Score and prediction of morbidity in women undergoing hysterectomy for malignancy. Gynecol Oncol. 2015;136(3):516–20.

37. Bhandoria G, Mane JD. Can Surgical Apgar Score (SAS) Predict Postoperative Complications in Patients Undergoing Gynecologic Oncological Surgery? Indian J Surg Oncol. 2020;11(1):60–5.

38. Teoh D, Halloway RN, Heim J, Vogel RI, Rivard C. Evaluation of the American College of Surgeons National Surgical Quality Improvement Program Surgical Risk Calculator in Gynecologic Oncology Patients Undergoing Minimally Invasive Surgery. J Minim Invasive Gynecol. 2017;24(1):48–54.

39. Iyer R, Gentry-Maharaj A, Nordin A, Burnell M, Liston R, Manchanda R, et al. Predictors of complications in gynaecological oncological surgery: a prospective multicentre study (UKGOSOC—UK gynaecological oncology surgical outcomes and complications). Br J Cancer. 2015;112(3):475–84.

40. Zullo F, Falbo A, Palomba S. Safety of laparoscopy vs laparotomy in the surgical staging of endometrial cancer: a systematic review and metaanalysis of randomized controlled trials. Am J Obstet Gynecol. 2012;207(2):94–100.

41. Barrie A, Freeman AH, Lyon L, Garcia C, Conell C, Abbott LH, et al. Classification of Postoperative Complications in Robotic-assisted Compared With Laparoscopic Hysterectomy for Endometrial Cancer. J Minim Invasive Gynecol. 2016;23(7):1181–8.

42. Jorgensen SL, Mogensen O, Wu C, Lund K, Iachina M, Korsholm M, et al. Nationwide Introduction of Minimally Invasive Robotic Surgery for Early-Stage Endometrial Cancer and Its Association With Severe Complications. JAMA Surg. 2019;154(6):530.

43. The COMET Initiative. COMET database [Internet]. [cited 2020 Nov 20]. Available from: https://www.comet-initiative.org/studies/

TABLES AND FIGURE CAPTION LIST

Figure 1: Study flow chart

Phase 1: we calculated the correlation, concordance, and agreement of the sagittal abdominal diameter measurements. This process was repeated three times, one for each sagittal abdominal diameter (defined by their anatomical landmark: the umbilicus, left renal vein, and inferior mesenteric artery).

? Inter-rater variation: A (A1+A2) vs B (B1+B2) measurements (n=60)

- Intra-rater variation: first (A1+B1) vs second (A2+B2) measurements (n=60)

Phase 2: Group 2 patients were randomized to the transperitoneal or extraperitoneal technique in the original trial (STELLA-2), and then were classified according to the minimally invasive approach (conventional or robotic-assisted). Patients with missing data were excluded.

Figure 2: Sagittal abdominal diameter (SAD) measurement and Inter-observer agreement

(a) Vertical white arrow shows sagittal abdominal diameter (SAD) measurement: the largest skin-to-skin distance perpendicular to the table. Arrowhead (yellow) indicates anatomical landmarks for each location: the umbilicus, the left emerging renal vein, and the emerging inferior mesenteric artery.

(b) SAD values of observer A vs observer B for each corresponding measurement. The continuous line of equality (y=x) represents perfect concordance. The discontinuous line represents the relationship between the 2 readings. Umbilical SAD measurements are the most similar to the line of equality. In the left renal vein and inferior mesenteric artery measurements, the lines are almost parallel to the reference line, indicating a possible systematic error.

(c) Bland-Altman plots to compare agreement. Difference between the two measurements: the continuous line represents perfect agreement (Obs. A - Obs. B = 0). The discontinuous line represents the mean difference between the 2 readings. The grey area defines the limits of agreement (95% confidence interval). The agreement was best for umbilical measurements as they are closest to the reference line. For the other SAD measurements, several readings were outside the limits of agreement. Systematic bias was ruled out since perfect agreement (y=0) was within the confidence interval.

Figure 3: SAD and adverse surgical outcomes in the transperitoneal subgroup

u-SAD : Umbilical sagittal abdominal diameter, *WHR* : Waist-hip ratio, *BMI* : Body mass index, *AUC* : area under the curve (accuracy)

(a) Mean umbilical SAD measurements in patients with and without surgical morbidity were 249 mm (95%CI, 233–265) and 219 mm (95%CI, 207–231), respectively.

(b) Surgical morbidity rate according to u-SAD measurements in the transperitoneal and extraperitoneal subgroups.

(c) Comparison of diagnostic accuracy of three anthropometric measurements to assess surgical morbidity. AUC values (95%CI) for u-SAD, WHR and BMI were as follows: 0.73 (0.59–0.86), 0.71 (0.57–0.85), and 0.67 (0.52–0.83). Comparison of u-SAD vs. WHR and u-SAD vs. BMI were not significant (p =0.4 and p =0.17, respectively).

(d) Diagnostic accuracy of u-SAD in the transperitoneal vs. extraperitoneal subgroups. AUC 0.73 (95%CI, 0.59–0.86) vs 0.50 (95%CI, 0.35–0.65), respectively.

* p <0.05

Table 1: Patients' characteristics and surgical outcomes

	Group 2 n=136	**Transperitoneal** n=64	**Extraperitoneal** n=72
Patient characteristics			
Body mass index (kg/m2)	29.5 (25.1–34.7)	28.3 (24.5–34.9)	30 (26.4–34.4)
Waist circumference (cm)	105 (96–115)	104 (96–115)	105 (96–115)
Waist-Hip ratio	0.91 (0.86–0.98)	0.92 (0.86–0.99)	0.90 (0.85–0.97)
Sagittal abdominal diameter (mm)	234 (208–265)	234 (208–265)	235 (212–265)
Age at surgery (years)	66 (61–73)	66 (60–74)	66 (61–72)

Comorbidity index [a]	3 (2–4)	3 (2–4)	3 (2–4)
Surgical outcomes			
Total operative time (min)	270 (240–300)	270 (240–300)	270 (225–315)
Para-aortic lymphadenectomy time (min)	90 (72–120)	90 (75–120)	90 (70–120)
Hematocrit drop [b]	6.6 (4.2–9.4)	6.3 (4.1–9.2)	6.7 (4.3–9.8)
Blood transfusion	6 (4.4)	3 (4.7)	3 (4.2)
Intraoperative complication	14 (10.3)	9 (14.1)	5 (6.9)
During para-aortic lymphadenectomy	6 (4.4)	4 (6.2)	2 (2.8)
[c]	8 (5.9)	5 (7.8)	3 (4.2)
Early postoperative complication	36 (26.5)	15 (23.4)	21 (29.2)
Related to para-aortic lymphadenectomy	2 (1.5)	1 (1.6)	1 (1.4)
[c]	11 (8.1)	7 (10.9)	4 (5.6)
Late postoperative complication	23 (16.9)	8 (12.5)	15 (20.8)
Related to para-aortic lymphadenectomy	1 (0.7)	0	1 (1.4)
[c]	13 (9.6)	6 (9.4)	7 (9.7)
Incomplete para-aortic lymphadenectomy	20 (14.7)	12 (18.8)	8 (11.1)
Laparoscopy conversion [d]	16 (11.8)	3 (4.7)*	13 (18.1)*
Surgical morbidity [e]	52 (43.7)	25 (44.6)	27 (42.9)

Data are expressed as either median (interquartile range) or numbers (percentage).

[a] Age-adjusted comorbidity index described by Charlson et al. [28]

[b] In patients presenting a drop in postoperative hematocrit, calculated as the difference between postoperative (within 48h post-surgery) and preoperative values. Six cases were excluded because of a gain in hematocrit values (corresponding to 6 transfusions).

[c] Surgical complications were classified using two corresponding classification systems: the ClassIntra for intraoperative adverse events [26], and the Dindo-Clavien[27] for postoperative complications.

[d] Including any of the following: laparotomy, extraperitoneal to transperitoneal, robotic-assisted to conventional

[e] The main outcome measure is defined in the text and table S1.

* The difference between the transperitoneal and extraperitoneal groups was significant (p =0.01), due to laparotomy conversions (0 vs. 6) and conversions from extraperitoneal to transperitoneal (6 cases).

SUPPORTING INFORMATION

Table S1: Surgical morbidity core outcome set definition

Category	Variable
Blood loss	Need for blood transfusion

Category	Variable
	Hematocrit drop >90th percentile (>11.8%)
Operative time	Total operative time >90th percentile (>350 min)
	LPAL operative time >90th percentile (>135 min)
Surgical complications	Intraoperative [?] grade III [a] or related to laparoscopic para-aortic lymphadenectomy [b]
	Postoperative (early or late) [c] [?] grade III or related to laparoscopic para-aortic lymphadenectomy
LPAL difficulty	LPAL uncompleted [d]
	LPAL converted [e]

Values in parenthesis indicate the corresponding percentiles in our cohort.

LPAL: laparoscopic para-aortic lymphadenectomy

[a] Adverse events were classified using two corresponding systems: ClassIntra for intraoperative[26] and Dindo-Clavien [27] for postoperative.

[b] The association between surgical complications and LPAL was specified as any of the following: vascular, nervous, intestinal or ureteral injury during para-aortic lymph node dissection, or para-aortic lymphocele/lymphocyst or lymphedema.

[c] Postoperative complications were classified according to the time of presentation: "early" within the first 30 days post-surgery, and "late" more than 30 days after surgery.

[d] LPAL was considered incomplete if no lymph nodes were obtained from all of the areas specified by the European Society of Gynecologic Oncology guidelines [3].

[e] Conversion was recorded as follows: from laparoscopy to laparotomy, from extraperitoneal to transperitoneal, or from robotic-assisted to conventional laparoscopy.

Table S2: Inter-rater agreement of SAD measurement (between observer A and observer B)

SAD	**Observer A**	**Observer B**	**Mean difference**				
(95% CI)	**Limits of agreement**	r	ρ_S **(95% CI) ***	**Bias**			
Umbilicus	231 ± 40	235 ± 36	-4 (-7.4; -0.5)	-22.5; 14.6	0.98	0.96 (0.94;0.99)	0.99
	219 (154–311)	234 (175–306)					
Left renal vein	238 ± 32	242 ± 31	-4.2 (-7.1; -1.2)	-19.9; 11.6	0.97	0.96 (0.93;0.99)	0.99
	238 (163–294)	247 (170–295)					
Inferior mesenteric artery	233 ± 34	243 ± 30	-10.1 (-14.3; -5.9)	-32.4; 12.2	0.94	0.89 (0.82;0.97)	0.95
	223 (171–297)	247 (171–297)					

Data are in mean ± standard deviation or median (range)

SAD : sagittal abdominal diameter, *CI* : confidence interval,r : Pearson's correlation coefficient, ρ_c : Lin's concordance correlation coefficient [30].

Bias is calculated by the quotient ofρ_c /r , a value of 1 indicates no bias.

* $p < 0.001$ for all measures.

Table S3. Intra-rater agreement of SAD measurement (between first and second measurements)

SAD	**1st measure**	**2nd measure**	**Mean difference (95% CI)**	**Limits of agreement**	r	**ρ_c* (95% CI)**
Umbilicus	233 ± 38	232 ± 38	0.97 (-0.73; 2.67)	-8.1; 10.1	0.993	0.99 (0.99;0.99)
	221 (154-310)	220 (155-311)				
Left renal vein	239 ± 32	240 ± 31	-0.63 (-1.78; 0.52)	-6.8; 5.5	0.995	0.99 (0.99;1)
	241 (163-294)	241 (166-295)				
Inferior mesenteric artery	238 ± 32	237 ± 33	0.50 (-1.63; 2.63)	-10.9; 11.9	0.984	0.98 (0.97; 1)
	236 (164-299)	234 (164-296)				

Data are in mean ± standard deviation or median (range)

SAD : sagittal abdominal diameter, *CI* : confidence interval,r : Pearson's correlation coefficient, ρ_c : Lin's concordance correlation coefficient [30].

Bias was calculated by the quotient ofρ_c /r , for all measurements and the result was = 1 (indicating no bias).

* $p < 0.001$ for all measures.

Table S4: Patients' characteristics and detailed surgical outcomes in Group 2 and all subgroups

	Group 2 n=136	**Transperitoneal** n=64	**Extraperitoneal** n=72	**Conventional laparoscopy** n=79	**Robotic-assisted laparoscopy** n=57
Patient characteristics					
Body mass index (kg/m2)	29.5 (25.1–34.7)	28.3 (24.5–34.9)	30 (26.4–34.4)	28.7 (24.8–32.9)	31 (27.1–35.2)
Waist circumference (cm)	105 (96–115)	104 (96–115)	105 (96–115)	103 (90–110)	107 (100–118)
Waist-Hip ratio	0.91 (0.86–0.98)	0.92 (0.86–0.99)	0.90 (0.85–0.97)	0.91 (0.84–1.0)	0.90 (0.86–0.96)

Sagittal abdominal diameter (SAD) (mm)	234 (208–265)	234 (208–265)	235 (212–265)	230 (202–261)	246.5 (221–272)
Age at surgery (years)	66 (61–73)	66 (60–74)	66 (61–72)	67 (61–73)	65 (60–73)
Comorbidity index [a]	3 (2–4)	3 (2–4)	3 (2–4)	3 (2–4)	3 (2–4)
FIGO stage					
Ia	43 (31.6)	22 (34.4)	21 (29.2)	29 (36.7)	14 (24.6)
Ib	33 (24.3)	16 (25)	17 (23.6)	21 (26.6)	12 (21.1)
II	32 (23.5)	17 (26.6)	15 (20.8)	12 (15.2)	20 (35.1)
IIIa	5 (3.7)	2 (3.1)	3 (4.2)	3 (3.8)	2 (3.5)
IIIb	2 (1.5)	1 (1.6)	1 (1.4)	1 (1.3)	1 (1.8)
IIIc1	6 (4.4)	1 (1.6)	5 (6.9)	3 (3.8)	3 (5.3)
IIIc2	14 (10.3)	5 (7.8)	9 (12.5)	9 (11.4)	5 (8.8)
IVa	1 (0.7)	0	1 (1.4)	1 (1.3)	0
FIGO tumor Grade					
1	11 (8.1)	6 (9.4)	5 (6.9)	10 (12.7)	1 (1.8)
2	55 (40.4)	24 (37.5)	31 (43.1)	25 (31.6)	30 (52.6)
3	70 (51.5)	34 (53.1)	36 (50)	44 (55.7)	26 (45.6)
Lymphovascular space invasion					
Yes	49 (36)	23 (36)	26 (36.1)	29 (36.7)	20 (35.1)
No	87 (64)	41 (64)	46 (63.9)	50 (63.3)	37 (64.9)
Type of surgery					
Hysterectomy	127 (93.4)	60 (93.8)	67 (93.1)	74 (93.7)	53 (93)
Unilateral or bilateral salpingo-oophorectomy	128 (94.1)	62 (96.9)	66 (91.7)	74 (93.7)	54 (94.7)
Pelvic lymphadenectomy	132 (97.1)	64 (100)	68 (94.4)	75 (94.9)	57 (100)
Para-aortic lymphadenectomy	125 (91.9)	57 (89.1)	68 (94.4)	72 (91.1)	53 (93)
Other procedures [b]	49 (36)	24 (37.5)	25 (34.7)	38 (48.1)	11 (19.3)
Surgical outcomes					
Total operative time (min)	270 (240–300)	270 (240–300)	270 (225–315)	285 (240–330)	265 (230–295)
Para-aortic lymphadenectomy time (min)	90 (72–120)	90 (75–120)	90 (70–120)	90 (75–120)	90 (70–100)
Hematocrit drop [c]	6.6 (4.2–9.4)	6.3 (4.1–9.2)	6.7 (4.3–9.8)	7.2 (4.3–9.8)	5.9 (4.2–8.2)
Blood transfusion	6 (4.4)	3 (4.7)	3 (4.2)	4 (5.1)	2 (3.5)

Intraoperative complication	14 (10.3)	9 (14.1)	5 (6.9)	12 (15.2)	2 (3.5)
Related to para-aortic lymphadenectomy [d]	6 (4.4)	4 (6.2)	2 (2.8)	5 (6.3)	1 (1.8)
	8 (5.9)	5 (7.8)	3 (4.2)	7 (8.9)	1 (1.8)
Early postoperative complication	36 (26.5)	15 (23.4)	21 (29.2)	21 (26.6)	15 (26.3)
Related to para-aortic lymphadenectomy [d]	2 (1.5)	1 (1.6)	1 (1.4)	2 (2.5)	0
	11 (8.1)	7 (10.9)	4 (5.6)	7 (8.9)	4 (7)
Late postoperative complication	23 (16.9)	8 (12.5)	15 (20.8)	15 (19)	8 (14)
Related to para-aortic lymphadenectomy [d]	1 (0.7)	0	1 (1.4)	0	1 (1.8)
	13 (9.6)	6 (9.4)	7 (9.7)	7 (8.9)	6 (10.5)
Incomplete para-aortic lymphadenectomy	20 (14.7)	12 (18.8)	8 (11.1)	11 (13.9)	9 (15.8)
Laparoscopy conversion [e]	16 (11.8)	3 (4.7)*	13 (18.1)*	8 (10.1)	8 (14)
Surgical morbidity [f]	52 (43.7)	25 (44.6)	27 (42.9)	33 (48.5)	19 (37.3)

Data are expressed as either median (interquartile range) or numbers (percentage).

[a] Age-adjusted comorbidity index described by Charlson et al. [28]

[b] Additional procedures included: peritoneal biopsies, omentectomy, appendectomy, sentinel lymph node biopsy, amongst others.

[c] In patients presenting a drop in postoperative hematocrit, calculated as the difference between postoperative (within 48h post-surgery) and preoperative values. Six cases were excluded because of a gain in hematocrit values (corresponding to 6 transfusions).

[d] Surgical complications were classified using two corresponding classification systems: the ClassIntra for intraoperative adverse events [26], and the Dindo-Clavien[27] for postoperative complications.

[e] Including any of the following: laparotomy, extraperitoneal to transperitoneal, robotic-assisted to conventional

[f] This main outcome measure is defined in table 1.

* The difference between the transperitoneal and extraperitoneal groups was significant (p =0.01), due to laparotomy conversions (0 vs. 6) and conversions from extraperitoneal to transperitoneal (6 cases).

Figure S1: Relationship between SAD and the rates of conversion and LPAL completion

SAD : sagittal abdominal diameter

* $p < 0.05$

Figure S2: Distribution of aortic lymph node count and u-SAD according to lymphadenectomy technique

u-SAD : umbilical sagittal abdominal diameter

Pearson correlation in T group: p <0.001, in X group:p =0.115

Linear regression analysis showed that for every additional centimetre of u-SAD, a transperitoneal aortic lymphadenectomy would obtain approximately one aortic lymph node less (+1 cm u-SAD [?] -1 aortic lymph node). Model equation: nº aortic nodes = 33.5 + SAD x -0.093