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Robotic Surgery Versus Conventional Laparoscopy and Laparotomy for Ovarian Cancer: A Systematic Review and Meta-analysis

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Abstract
Background: This research aimed to evaluate differences in overall survival, recurrence frequency, and both intraoperative and postoperative results in ovarian cancer (OC) patients treated with robotic surgery, laparoscopic procedures, or open laparotomy.
Methods: In this study, comprehensive searches were done in PubMed, Web of Science, Embase, and Scopus until September 15, 2023. The main outcome was to compare the association between robotic surgery and other approaches: overall mortality rate, recurrence rate, postoperative and intraoperative complications, blood transfusion, duration of operation, conversion to open, estimated blood loss (EBL), pelvic/para-aortic lymph nodes, and duration of stay in the hospital.
Results: Ultimately, a total of 9 studies were included. Robotic surgery had a significant relationship between the lowest EBL and the duration of stay in the hospital in comparison with laparotomy, with a mean difference of -292.26 mL and -3.54 days, respectively. Also, the rate of postoperative complications (OR: 0.41), blood transfusion (OR: 0.03), lower overall mortality (OR: 0.22), and recurrence rate (OR: 0.48) were lower in robotic surgery in comparison with laparotomy. In addition, robotic surgery had significantly shorter operation times than laparoscopy, with a mean difference of -33.21 minutes. Furthermore, the rate of blood transfusion (OR: 0.10) and conversion to open (OR: 0.35) were lower in robotic surgery in comparison with laparotomy.
Conclusion: This study demonstrated that robotic surgery could be a safe, viable, and effective alternative for those suffering from OC, offering lower rates of conversion to open surgery and blood transfusion compared to laparoscopy.
Keywords: Ovarian neoplasms, Neoplasm staging, Robotic surgery, Cytoreduction, Minimally invasive surgical procedures

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Introduction

Ovarian cancer (OC) ranks as the eighth most prevalent women's cancer globally and stands as the fifth leading cause of death in this population (1). Each year, over 300 000 women are affected by OC, and approximately 152 000 women lose their lives to it (2). These statistics underscore the danger posed by this illness to the well-being and survival of women (2). The International Federation of Gynecology and Obstetrics reported that the preferred treatment approach includes thorough surgical staging (3). This includes a series of methods like hysterectomy, omentectomy, bilateral adnexectomy, aortic and pelvic lymphadenectomy, along with the collection of multiple peritoneal biopsies. Additionally, an appendectomy may be performed, particularly in cases involving mucinous histology (3). Traditionally, these procedures have been conducted using a laparotomy approach involving an extended midline incision (4). The primary goal was to achieve precise disease diagnosis and staging while also striving for maximal cytoreduction, aiming to eliminate all visible signs of the disease (5). In recent decades, laparoscopic surgery has become a key component of standard surgical practice, providing a minimally invasive alternative. As a result, its benefits over laparotomy were well-established, such as the use of smaller incisions and enhanced intraoperative visualization (6). However, laparoscopy also presented several challenges, such as unnatural hand movements, non-wristed instruments, dependence on two-dimensional (2D) visuals, limited depth perception, camera instability, the requirement for expert surgical assistance, longer learning curves, and limited range of motion (7).

In studies primarily involving traditional laparoscopy, minimally invasive surgery (MIS) has demonstrated comparable overall survival and recurrence rates to open laparotomy in early-stage OC (8-10). Additionally, MIS offers the benefits of smaller incisions, shorter hospital stays, and reduced bleeding (4). The National Comprehensive Cancer Network (NCCN) reported that MIS is used for carefully selected OC patients, provided they are under the care of skilled physicians (11). The da Vinci robotic-assisted laparoscopy system, created by Intuitive Surgical in Sunnyvale, CA, USA, was granted FDA approval for gynecological procedures in 2005 (12, 13). Over time, robotic technology has been steadily integrated into the toolkit of gynecological oncological surgeons. This integration has brought about significant shifts in practice patterns and surgical approaches when managing gynecological malignancies (14). However, there are drawbacks, including high costs, the absence of haptic feedback, and, notably for gynecological oncologists, insufficient availability of the whole four abdominal quadrants simultaneously (15,16). Also, the previous studies did not establish a clear role of robotic surgery in OC patients.

This research aimed to compare the intraoperative outcome, postoperative complications, overall survival, and recurrence rate between robotic surgery and laparoscopy and laparotomy surgery in OC patients.

Methods

Systematic literature search

We followed the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA). Comprehensive searches were done in PubMed, Web of Science, Embase, and Scopus up to September 15, 2023, utilizing the following keywords: ("robot" OR "robots" OR "robotically" OR "robotics" OR "robotics" OR "robotic" OR "robotization" OR "robotized" OR "robots" OR "Da Vinci" OR "robotic-assisted" OR "robot-assisted") AND ("ovarian cancer" OR "carcinoma of ovary" OR "ovarian carcinoma" OR "ovary cancer" OR "oophoroma"). In addition, the references of relevant studies were used for the manual searching. Table S1 shows the detailed search strategy for each database.

Inclusion and exclusion criteria

All clinical trials and observational investigations (prospective and retrospective) comparing both robotic surgical interventions with either laparoscopic or laparotomic approaches in individuals diagnosed with OC were included. The study inclusion criteria were: 1) Inclusion of diagnosed OC patients; 2) Inclusion of those who underwent initial or interval debulking or surgical staging for OC; 3) Inclusion of patients, whether they received neoadjuvant chemotherapy or not; and 4) Inclusion of literature published in English.

In addition, studies with incomplete data, case report papers, abstracts published in conferences, reviews, editorials, and non-English-published studies were excluded from this study.

Outcome measures

The primary outcome was to compare the following results between robotic surgery with laparoscopy or laparotomy: overall mortality rate, recurrence rate, postoperative and intraoperative complications, estimated blood loss (EBL), blood transfusion, length of stay in the hospital, conversion to open, duration of operation, and para-aortic/pelvic lymph nodes.

Study selection

Two independent reviewers initially conducted a comprehensive assessment of the papers by evaluating their titles and abstracts after the removal of duplicate entries. Subsequently, the remaining articles underwent a thorough examination of their complete content. If any discrepancies arose, a third reviewer was brought in to settle the differences.

Data extraction

Data extraction was conducted by two separate reviewers, and a third independent reviewer was involved to resolve any inconsistencies that emerged.

Quality assessment

The quality of the studies included was assessed by two independent reviewers, with any disputes settled through consultation with a third reviewer. The Newcastle–Ottawa Scale (NOS) was utilized (17), which includes three main elements—selection, comparability, and outcome—to evaluate the potential bias in the studies incorporated into our analysis.

Statistical analysis

The data were extracted in terms of mean ± SD, with some variables provided as median and interquartile range or mean and range. To ensure consistency, we applied the conversion formulas of different studies (18-20). Data were analyzed using Stata/SE, version 17, developed by StataCorp LLC. The odds ratio was estimated from the log odds ratio using the following formula: odds ratio = $e^{\text{log odds ratio}}$. Heterogeneity was assessed using the I^2 statistic, where studies with an I^2 greater than 50% were considered highly heterogeneous. In situations with high heterogeneity, a random effects analysis was applied, whereas for variables with lower heterogeneity, a fixed effects analysis was used. For each parameter, we reported the mean difference along with its corresponding 95% confidence intervals (CIs), using a statistical significance cutoff of 0.05.

Publication bias

Egger's linear regression test, funnel plots, Trim and

Fill analyses were used for assessing publication bias. Whenever we detected funnel plot asymmetry, we applied the Trim and Fill analysis method to identify potentially omitted studies.

Results

Study selection

The initial search yielded 2172 articles. After removing 802 duplicates, 1318 studies were eliminated based on a review of titles/abstracts. Following this, 52 full-text papers were evaluated for eligibility, and ultimately, 9 studies were included in the study. The selection procedure is summarized in a PRISMA flow diagram (Figure 1).

Characteristics of included studies

As shown, the research was conducted between 2013 and 2022 (Table 1). Robotic, laparoscopic, and laparotomy groups consist of 936, 1595, and 428 patients, respectively. The type of surgery was tumor staging in 3 studies. In addition, three studies consisted of patients who underwent debulking surgery. Three studies consisted of both tumor staging and debulking surgery. The mean age of patients who underwent robotic surgery was 44.3 to 66.2 years.

Robotic surgery versus laparotomy

As shown in Figure S1, 7 studies demonstrated the lower rate of EBL in robotic surgery in comparison with laparotomy with a mean difference of -292.26 mL (95% CI: -488.17, -96.35, $P<0.001$) (Figure S1). In addition, robotic surgery also had a significantly low rate of blood transfusion with an OR of 0.03 (95% CI: 0.01, 0.11, $P<0.001$) (Figure S2).

Furthermore, perioperative complications were not significantly varied between robotic surgery and laparotomy (OR: 0.44, 95% CI: 0.18, 1.01, $P=0.05$) (Figure S3). Nevertheless, the robotic surgery group experienced notably fewer postoperative complications than the laparotomy group, with an OR of 0.41 (95% CI: 0.26–0.67, $P<0.001$) (Figure S4). There were no differences between operative time in two groups (95% CI: -44.72, 36.04, $P=0.83$) (Figure S5). However, the robotic surgery group had a significantly shorter hospital stay than the laparotomy group with a mean difference of -3.54 days (95% CI: -4.53, -2.55, $P<0.001$) (Figure S6).

The number of paraaortic and pelvic lymph nodes yielded in robotic surgery and laparotomy showed no differences between the two groups (95% CI: -4.83, 4.87, $P=0.99$ and 95% CI: -2.64, 6.07, $P=0.44$, respectively) (Figures S7 and S8).

Finally, robotic surgery had a significantly lower overall mortality and recurrence rate compared to laparotomy, with ORs of 0.22 (95% CI: 0.07, 0.70, $P=0.01$) and 0.48 (95% CI: 0.27, 0.87, $P=0.02$), respectively (Figures S9 and S10).

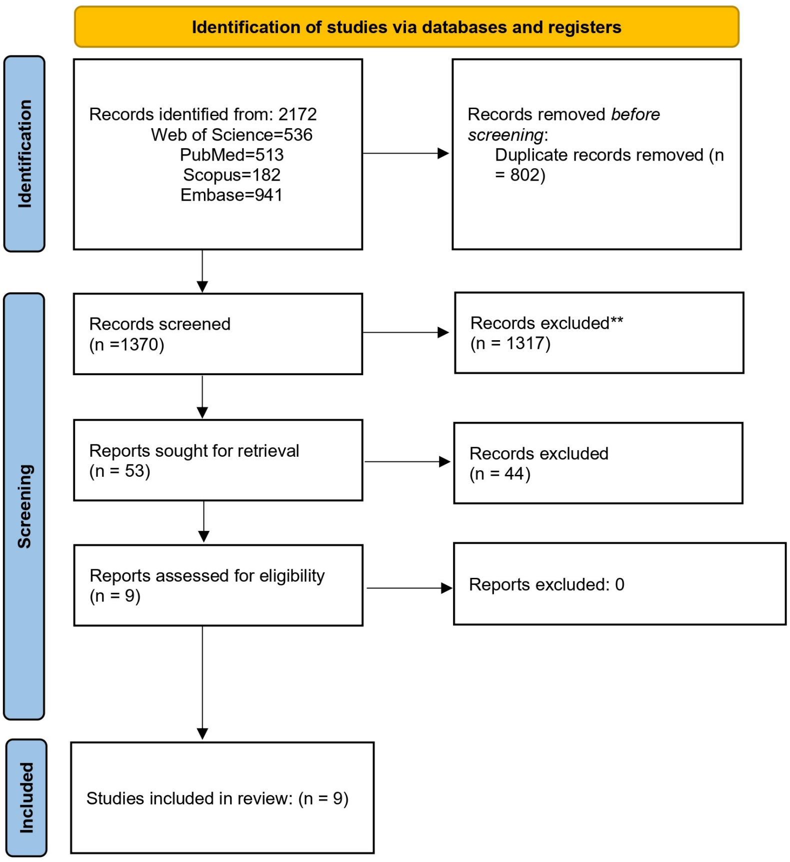

Figure 1. PRISMA flowchart of the included studies

Table 1. The baseline characteristics of the included studies

Study, year	Country	Design	Type of surgery	Groups	Number	Neoadjuvant	Age (years)	BMI (kg/m²)	Follow-up (months)	Outcomes
Van Trappen, 2022 (21)	Belgium	Retrospective	Debulking for advance cases and staging for initial cases	Robotic	47	In advanced cases (FIGO 3C and 4A)	Early stage 60.6 ± 13, advance stage: 60.7 ± 9.3)	Early stage: 26.3 ± 2.68 Advance stage: 27.8 ± 2.22	Early stage: Median 40 (range: 4–82) Advance stage: Median 52 (range 12–61)	Operation time, para-aortic lymph node, pelvic lymph node, intraoperative complication, postoperative complication, length of stay, tumor recurrence, EBL
				Laparotomy	49		Early stage 67.4 ± 11 advance stage: 67.6 ± 9.7	Early stage: 25.8 ± 3.81 Advance stage: 23.5 ± 2.97	Early stage: Median 45 (range 8–86) Advance stage: Median 31 (range 6–86)	
Magrina, 2013 (22)	USA	Retrospective	Primary debulking	Robotic	10	Platinum based chemotherapy after surgery	65.0 ± 13.19	27.0 ± 6.05	36	Operation time, para-aortic lymph node, pelvic lymph node, intraoperative complication, postoperative complication, length of stay, tumor recurrence, EBL, Overall survival
				Laparotomy	33		62.3 ± 11.22	22.6 ± 1.84	36	
				Laparoscopy	9		60.0 ± 11.41	25.8 ± 4.39	36	
Facer, 2019 (23)	USA	Retrospective	Debulking	Robotic	636	33 patients	Median (IQR) 56 (47-65)	NA	Median (IQR): 37.8 (25.2-52.6)	Length of stay, Overall survival, conversion to open
				Laparoscopy	1265		Median (IQR) 55 (45-65)	NA	Median (IQR): 37.5 (25.1-52.8)	
Bellia, 2016 (24)	France and Italy	Retrospective	Staging and treatment surgery	Robotic	16	10 (62.5 %)	47.3 ± 12.3	22.3 ± 2.9	21.2 ± 12.7	Operation time, pelvic lymph node, intraoperative complication, postoperative complication, length of stay, tumor recurrence, blood transfusion, Overall survival
				Laparoscopy	23	13 (56.8 %)	49.4 ± 15.9	25.8 ± 6.5	18.5 ± 8.6	
Zhang, 2021 (25)	USA	Retrospective	Interval debulking	Robotic	43	All patients	66.2	27.3	Median: 31.8	Operation time, postoperative complication, length of stay, tumor recurrence, blood transfusion, EBL, Overall survival
				Laparotomy	50		63.0	27.7	Median: 27.0	
Feuer 2013 (26)	USA	Retrospective	Initial staging, or debulking after neoadjuvant chemotherapy	Robotic	63	33 (52.4)	59.8 ± 11.8	27.1 ± 7.3	15.5 ± 12.3	Operation time, intraoperative complication, postoperative complication, length of stay, tumor recurrence, EBL, Overall survival
				Laparotomy	26	4 (15.4)	55.7 ± 11.7	28.2 ± 6.1	23.5 ± 14.0	
Chen, 2015 (27)	Taiwan	Retrospective	Tumor staging	Robotic	44	NA	44.3 (12.3)	22.3 (2.7)	13.1 (5.3)	Operation time, intraoperative complication, postoperative complication, length of stay, recurrence, EBL, Overall survival, conversion to open
				Laparotomy	73		49.2 (12.8)	22.9 (4.2)	26.7 (17.7)	
				Laparoscopy	21		43.8 (10.3)	24.1 (4.9)	29.6 (19.0)	
Cianci, 2022 (28)	Italy	Retrospective	Fertility sparing, radical surgical staging, restaging	Robotic	45	31	50.0 ± 10.7	24.8 ± 6.6	24.8 ± 6.6	Operation time, para-aortic lymph node, pelvic lymph node, intraoperative complication, postoperative complication, length of stay, recurrence, EBL, conversion to open
				Laparotomy	197	157	55.4 ± 12.8	25.5 ± 5.5	24.5 ± 5.8	
				Laparoscopy	213	153	51.0 ± 13.4	24.5 ± 5.8	25.5 ± 5.5	
Gallotta, 2016 (29)	Italy	Retrospective	Tumor staging	Robotic	32	72 patients	Median 49 (32-76)	Median 24 (17-54)	Median 38	Operation time, para-aortic lymph node, pelvic lymph node, intraoperative complication, postoperative complication, length of stay, EBL, conversion to open
				Laparoscopy	64		Median 49 (27-73)	Median 24 (19-41)		

NA: not applicable, EBL: estimated blood loss.

Robotic surgery versus laparoscopy

There have been no differences in EBL between the two groups (95% CI: -173.36, 39.76, $P=0.22$) (Figure S11). However, blood transfusion was significantly lower in robotic surgery in comparison with laparoscopic with an OR of 0.10 (95% CI: 0.01, 0.89, $P=0.04$) (Figure S12).

In addition, there were no significant differences in postoperative and intraoperative complications between the two groups (95% CI: 0.37, 3.97, $P=0.74$ and 95% CI: 0.60, 2.64, $P=0.54$, respectively (Figures S13 and S14). In addition, there was a low rate of conversion to open in robotic surgery compared to laparoscopic with an OR of 0.35 (95% CI: 0.26, 0.49, $P<0.001$) (Figure S15).

Robotic surgery had significantly lower operation time compared to laparoscopic with a mean difference of -33.21 minutes (95% CI: -49.39, -17.03, $P<0.001$) (Figure S16). However, there were no significant differences in duration of staying in hospital between the two groups (95% CI: -1.97, 0.02, $P=0.06$) (Figure S17).

Furthermore, significantly more pelvic lymph node yield in robotic surgery in comparison with laparoscopic with a mean difference of 3.81 (95% CI: 1.88, 5.73, $P<0.001$) (Figure S18). However, there were no significant differences in the number of paraaortic lymph nodes between the two groups (95% CI: -2.04, 1.69, $P=0.85$) (Figure S19).

Finally, there were no significant differences in the overall mortality and recurrence rate between the two groups (95% CI: 0.37, 3.29, $P=0.85$ and 95% CI: 0.16, 1.65, $P=0.26$, respectively) (Figures S20 and S21).

Study quality assessment and publication bias

Bias assessment in the studies included in this research was conducted using the NOS scale, with detailed score information provided in Table 2. No significant publication bias was observed for study outcomes.

Discussion

Our meta-analysis included nine studies with 2959 patients. Our results revealed that there was a low rate of postoperative complications in robotic surgery, blood transfusion, EBL, duration of stay in the hospital, and overall mortality and recurrence rate compared to laparotomy in patients with OC. In addition, perioperative complications, operative time, robotic surgery, and laparotomy approaches do not significantly differ in the number of paraaortic and pelvic lymph nodes. Furthermore, robotic surgery had a significantly brief operation time, lower rates of blood transfusion, lower rates of conversion to open, and a higher rate of pelvic lymph node yield compared to the laparoscopy approach in patients with OC.

Furthermore, there were no significant differences between robotic and laparoscopic approaches in terms of EBL, postoperative and intraoperative complications, recurrence rate, overall mortality, hospital stay duration, and the number of paraaortic lymph nodes retrieved.

MIS techniques, encompassing both conventional laparoscopy and robotic surgery, are achieving a widespread reputation in the surgical treatment of OC. Robotic surgery stands as one of the most recent advancements embraced by gynecologic surgeons across the United States and many countries worldwide (30,31). Robotic-assisted MIS has demonstrated its efficacy and feasibility in staging and treating endometrial and cervical cancer (32,33). Conversely, the role of robotic surgery in both initial and secondary OC remains an area of ongoing investigation (34).

For patients with OC, the main goal of debulking surgery is the complete elimination of residual disease (35). Critics contend that the lack of tactile feedback during MIS may lead to higher rates of undetected residual disease and that MIS could be linked to cancer spread or incomplete resection of large tumors (36). Studies of MIS for gynecological malignancies have conflicting results. Perioperative outcomes are enhanced with MIS while maintaining survival in early-stage endometrial cancer (37,38).

Table 2. The NOS score of the included studies

Study	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that the outcome of interest was not present at the start of the study	Comparability of cases and controls based on the design or analysis	Assessment of outcome	Was the follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts	Total
Bellia (24)		*	*	*	No	Yes	*	No star	5
Chen (27)	*	*	*	*	No	Yes	*	No star	6
Cianci (28)	*	*	*	*	No	*	*	No star	6
Feuer (26)	*	*	*	*	No	Yes	*	*	7
Gallotta (29)	*	*	*	*	*	Yes	No	No	6
Magrina (22)	No	*	*	*	No	Yes	*	*	6
Van Trappen (21)	*	*	*	*	No	Yes	*	No	6
Facer (23)	*	*	*	*	*	*	*	No	7
Zhang (25)	*	*	*	*	*	*	*	No	7

On the other hand, MIS radical hysterectomy has been shown to be inferior to the open approach in early-stage cervical cancer patients (39,40). However, our results showed that robotic surgery had significantly lower overall mortality, recurrence rate, and postoperative complications compared to laparotomy in patients with OC. In addition, there were no differences in overall mortality and recurrence rates between the two MIS approaches, robotic and laparoscopic. Similarly, previous meta-analyses showed similar or superior survival rates in robotic surgery compared to laparotomy in patients with OC (41-43).

When it comes to managing primary or recurrent OC, robotic surgery offers distinct advantages, such as reduced EBL and shorter hospital stays, in comparison to traditional laparotomy (44). A previous study recommended opting for robotic surgery over laparotomy for endometrial cancer staging due to several benefits, including reduced hospital stays, diminished EBL, lower postoperative complication rates, and an increase in the patient's body mass index (BMI) (45). A prior study demonstrated that robotic surgery and laparoscopy yielded comparable outcomes in radical hysterectomy and the management of ovarian remnant syndrome, making them more favorable options compared to laparotomy. This choice was associated with shorter hospital stays, fewer postoperative complications, and reduced blood loss (46,47). In line with these results, our study demonstrated that, compared to laparotomy, robotic surgery was associated with lower rates of postoperative complications, EBL, and blood transfusion and a shorter hospital stay in patients with OC. In addition, our results showed that robotic surgery exhibited notable advantages in patients with OC, including significantly lower rates of blood transfusions, lower rates of conversion to open surgery, shorter operation times, and a higher yield of pelvic lymph nodes, in comparison with the laparoscopic approach. Furthermore, robotic surgery, utilizing a computer-assisted platform, serves as an advanced evolution of traditional laparoscopy, overcoming its limitations, including restricted instrument mobility, 2D visualization, and ergonomic difficulties for the surgeon (48).

The cost of robotic utilization is another concern. Previous studies showed that utilizing robotic surgery in the gynecology major is associated with higher costs (49). However, our findings suggest that robotic surgery is linked to a shorter hospital stay and fewer complications, which could offset the increased costs.

Although our study showed the advantages of robotic surgery in patients with OC, several limitations should be considered. Crucially, it is essential to note that all studies incorporated into this study had a retrospective design. Selection bias may arise from the absence of random allocation, necessitating cautious interpretation of the meta-analysis findings, as surgical decision-making could influence the results. Second, subgroup analysis and meta-regression analysis, which would have provided insights into tumor stages, follow-up duration, age, and race, could not be conducted because of the lack of enough demographic information and the limited number of included studies. Third, most meta-analyses had high heterogeneity, which can be due to different patients' demographics, types of OC cancer, types of surgery, and stage of tumor. Future randomized controlled trials with long follow-ups are recommended to evaluate the efficacy and safety of robotic surgery, specifically in advanced OC.

Conclusion

In conclusion, our results showed that robotic surgery caused the lowest loss of blood, blood transfusion, rate of postoperative complications, duration of stay in the hospital, and overall mortality and recurrence rate in comparison with laparotomy among OC patients. In addition, robotic surgery is considered by a low rate of blood transfusion, the rate of conversion to open, operation time, as well as a higher rate of pelvic lymph node yield compared to the laparoscopy approach in patients with OC.

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Authors' Contribution

Conceptualization: Shadi Moloughi, Amin Dalili.
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Visualization: Shadi Moloughi.
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Competing Interests

The authors declare that they do not have any conflict of interest.

Ethical Approval

As this study is based on previously published data, ethical approval was not applicable.

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Supplementary Files

Supplementary file 1 contains Table S1 and Figures S1-S21.

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