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Robotic Metabolic and Bariatric Surgery: The First Reported Malaysian Series and a Propensity-Matched Comparison with Laparoscopic Surgery

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Abstract

Introduction

Robotic metabolic and bariatric surgery (MBS) is expanding unevenly worldwide; no Malaysian robotic MBS series has previously been reported. We describe this series, its single-surgeon operative-time learning curve, and outcomes versus laparoscopic bariatric surgery (LBS).

Methods

Retrospective cohort across three private tertiary hospitals, August 2018–January 2024. All 58 robotic cases underwent learning-curve analysis; 50 were matched 1:1 to same-surgeon LBS controls by exact procedure and conversion status plus propensity score. Segmented regression estimated the operative-time breakpoint.

Results

Fifty-two robotic cases (89.7%) were gastric bypass or sleeve-plus and 9 (15.5%) were conversions; body mass index remained imbalanced after matching (standardized mean difference 0.18). Robotic operative time exceeded LBS by 54 minutes (95% exact CI 45.5–68.5; $P < 0.001$). The breakpoint occurred at case 31.9 (95% CI 26.4–37.2); mean operative time was 208 minutes for cases 1–31 and 154 minutes thereafter. Major complications occurred in 1 robotic and 2 laparoscopic patients (exact McNemar $P = 1.000$). The matched analysis included 50 pairs with complete measured 12-month weight data. Mean %TWL was 31.8% versus 31.5% (paired difference 0.30 percentage points; 95% CI -1.85 to 2.45; $P = 0.78$).

Conclusion

Selective robotic implementation showed an operative-time transition at approximately 30 cases but retained a 54-minute time premium. Major complications were sparse and estimates for complications and 12-month weight loss did not establish equivalence. These findings establish neither robotic superiority nor a case for routine substitution.

Key Points

• First Malaysian series of robotic metabolic and bariatric surgery.

• Single-surgeon operative time transitioned after approximately 30 robotic cases.

• Robotic operative time was 54 minutes longer than matched laparoscopy.

• Major complications were sparse; comparative precision was limited.

Introduction

Metabolic and bariatric surgery (MBS) is the most effective durable treatment for severe obesity [1], and laparoscopy remains its established minimally invasive approach. In Malaysia, the National Health and Morbidity Survey 2023 reported overweight or obesity in 54.4% of adults, up from 50.1% in 2019 [2]. Malaysian guidance includes SG, RYGB, and OAGB [3]; sleeve-plus procedures combine SG with an intestinal bypass.

Robotic platforms offer three-dimensional visualization, wristed instruments, and tremor filtration suited to intracorporeal suturing and reoperative dissection. Comparative evidence remains mixed: meta-analyses and database studies report comparable short-term outcomes but consistently longer operative times for robotic gastric bypass [4–8], and analyses of revision and conversion procedures suggest possible advantages although selection bias is difficult to exclude [9–11]. Registry data indicate higher complication rates for robotic primary SG [12], uptake has expanded unevenly [13], and published learning curves are heterogeneous, with transitions reported at differing case counts [14–17].

Almost all of this evidence originates from North America, Europe, and East Asia, where cost structures and platform access differ from Southeast Asian practice. No Malaysian series of robotic MBS has previously been reported. The aims were to describe case selection, to estimate a single-surgeon operative-time breakpoint, and to compare operative time, 30-day outcomes, and 12-month percentage total weight loss (%TWL) with matched laparoscopic controls.

Materials and Methods

Design, setting, and eligibility

This retrospective comparative cohort study used a prospectively maintained database from a collaborative program spanning three private tertiary hospitals in Malaysia, from August 2018 through January 2024. Reporting follows the STROBE statement [18]. Patients aged 18 years or older undergoing primary or conversion MBS were eligible if they met body mass index (BMI) criteria consistent with Malaysian clinical practice guidelines [3]: BMI 37.5 kg/m² or above, or 32.5 kg/m² or above with an obesity-related condition. Eligibility and exclusion criteria are detailed in Supplementary Methods. All conversions were from SG to RYGB. Procedures comprised SG, RYGB, OAGB, single-anastomosis duodenojejunal bypass (SADJB), single-anastomosis sleeve jejunal bypass (SASJB), and proximal jejunal bypass (PJB), the last three termed sleeve-plus. All 58 consecutive robotic cases entered the learning-curve cohort.

Platform allocation

The operating surgeon chose the approach after discussion with the patient. The robotic platform was preferentially considered for gastric bypass, conversion cases, and anatomy anticipated to be technically difficult; robot availability, funding, and patient preference also influenced allocation. Allocation was neither random nor protocol-driven, and confounding by indication cannot be excluded.

Program implementation, surgeon, and platform

Before the first local case, the team trained and developed protocols at a high-volume robotic surgery center in the Republic of Korea. The first three local cases were performed with an expert proctor present in an observational capacity; the proctor performed no part of any operation. All 58 robotic procedures and all matched laparoscopic controls were performed by a single console surgeon with 16 years of high-volume laparoscopic bariatric practice (approximately 200–500 procedures annually) and no previous independent robotic bariatric cases; a consistent core surgical and operating room team was maintained throughout. Cases used the da Vinci Si system through December 2022 (46 cases) and the Xi from January 2023 (12 cases).

Surgical technique

Technique was standardized across approaches. Dissection used ultrasonic shears, and anastomoses were linear-stapled except the SADJB anastomosis, which was hand-sewn. All stapling was performed with laparoscopic staplers in both approaches; robotic SureForm staplers were not used. The transition from the da Vinci Si to Xi platform therefore did not change the stapling method. For RYGB, the biliopancreatic limb measured 150 cm and the alimentary limb 50 cm; for OAGB, SADJB, and SASJB the bypassed limb measured 180 cm. Operative steps and perioperative care were otherwise identical between approaches; PJB details are provided in Supplementary Methods.

Matching, variables, and outcomes

Comparative analyses used 1:1 matching. Eligibility for matching required a procedure and conversion category represented in the robotic cohort, complete baseline matching variables, and a clinically measured 12-month weight within ± 3 months of the anniversary in both approaches. Procedure type and conversion status were matched exactly, and a logistic-regression propensity score included age, sex, BMI, type 2 diabetes, hypertension, and obstructive sleep apnea. Nearest-neighbor matching without replacement used a caliper of 0.2 SD of the logit [19]. Fifty robotic cases were matched to 50 of the 238 eligible same-surgeon laparoscopic procedures; eight robotic cases without an acceptable match were excluded from comparative analyses but retained in the learning-curve cohort (Fig. 1). Balance used standardized mean differences (SMDs), < 0.10 prespecified as acceptable.

Robotic skin-to-skin time was partitioned into docking, console, and undocking components. Leak, postoperative bleeding, readmission, and reoperation were defined a priori and assessed within 30 days (Supplementary Methods); endoscopic and radiologic procedures counted as interventions, not reoperations. Complications were graded by the Clavien–Dindo classification [20], grades III–V defined as major. Percentage total weight loss was (preoperative weight − 12-month weight) / preoperative weight × 100 [21], measured on calibrated scales within ± 3 months of the anniversary; data were locked in April 2025 and missing values were not imputed. Primary outcomes were the chronological change in

robotic operative time and the segmented breakpoint; secondary outcomes were operative-time components, the paired difference versus LBS, length of stay, 30-day outcomes, and 12-month %TWL.

Statistical analysis

Continuous variables are reported as mean ± SD or median (IQR). Quartiles used the SPSS HAVERAGE method, equivalent to the Hyndman–Fan type 6 estimator (R: quantile(..., type = 6)). Matched operative times were compared with paired Wilcoxon signed-rank tests; Hodges–Lehmann location shifts and exact 95% CIs were derived from Walsh averages. A one-breakpoint segmented linear regression modeled operative time by chronological case number (1–58), without procedure adjustment. The Davies test assessed slope change; 2,000 residual-bootstrap resamples provided percentile CIs for the breakpoint and slopes. CUSUM used 174 minutes, the cohort median, as its reference and therefore was not expected to end at zero. Docking and console times were available for 44/58 cases (75.9%). Because all missing component times occurred later, component summaries compare cases 1–25 with 26–58 descriptively; this split approximates the CUSUM maximum and is not the segmented-regression breakpoint.

Paired risk differences were calculated as (b - c)/n, where b and c denote robotic-only and laparoscopic-only events, with exact McNemar tests for any and major complication; CIs were not calculated because events were few. Twelve-month %TWL was analyzed with a paired t test. Post hoc sensitivity analyses repeated the segmented model after excluding SG and after adjustment for procedure type and conversion status. Residual BMI imbalance in operative time was explored with mixed-effects models containing a random intercept for matched pair. Post hoc sex-based analyses stratified the 50 matched pairs by sex. Robotic–laparoscopic differences in operative time, 12-month %TWL, and major complications were summarized separately for male and female pairs. No formal subgroup or interaction testing was performed because the study was not designed or powered to detect effect modification by sex; these analyses were post hoc and exploratory. Analyses used SPSS 29.0 (IBM Corp.) and R 4.2.2 with segmented [22], MatchIt [23], lme4, and lmerTest. Model specifications are provided in Supplementary Methods. Tests were two-sided at $P < 0.05$.

Results

Cohort and matching

Among 1,650 MBS procedures performed during the study period, 58 (3.5%) were robotic: 26 sleeve-plus (44.8%), 18 RYGBs (31.0%; 9 primary and 9 sleeve-to-RYGB conversions), 8 OAGBs (13.8%), and 6 SGs (10.3%). Fifty-two (89.7%) were gastric bypass or sleeve-plus procedures and 9 (15.5%) were conversions. Of the 1,592 laparoscopic procedures forming the source population, 238 (14.9%) met the matching eligibility criteria and 50 (21.0%) were selected as matched controls.

Age and the reported categorical covariates were closely balanced, and procedure type and conversion status were identical by design. BMI was slightly higher robotically (46.8 ± 2.3 versus 46.4 ± 2.2 kg/m²; SMD 0.18) (Table 1).

Table 1
Baseline characteristics of the 50 propensity-matched pairs

Characteristic	Robotic (n = 50)	Laparoscopic (n = 50)	SMD
Age (years), mean ± SD	47.2 ± 7.1	46.8 ± 7.3	0.06
Female sex, n (%)	36 (72.0)	36 (72.0)	0.00
BMI (kg/m²), mean ± SD	46.8 ± 2.3	46.4 ± 2.2	0.18
Type 2 diabetes, n (%)	31 (62.0)	31 (62.0)	0.00
Hypertension, n (%)	32 (64.0)	32 (64.0)	0.00
Obstructive sleep apnea, n (%)	30 (60.0)	30 (60.0)	0.00
Conversion surgery, n (%)	9 (18.0)	9 (18.0)	0.00
Sleeve gastrectomy	6	6	0.00
OAGB	6	6	0.00
RYGB	15	15	0.00
Primary	6	6	—
Sleeve-to-RYGB conversion	9	9	—
Sleeve-plus	23	23	0.00
SADJB	8	8	—
SASJB	8	8	—
PJB	7	7	—

BMI, body mass index; OAGB, one-anastomosis gastric bypass; PJB, proximal jejunal bypass; RYGB, Roux-en-Y gastric bypass; SADJB, single-anastomosis duodenojejunal bypass; SASJB, single-anastomosis sleeve jejunal bypass; SD, standard deviation; SMD, standardized mean difference. Procedure type and conversion status were matched exactly; all nine SG-to-RYGB conversions in the robotic cohort were matched to SG-to-RYGB conversions in the laparoscopic cohort. BMI remained above the prespecified balance criterion (SMD 0.18).

Operative time and learning curve

Among the 50 matched pairs, median operative time was 174 minutes (IQR 154–206) robotically and 120 minutes (IQR 106–142) laparoscopically. The Hodges–Lehmann paired difference was 54 minutes (exact 95% CI 45.5–68.5; paired Wilcoxon $P < 0.001$), with procedure-level estimates ranging from 34 minutes for RYGB to 69 minutes for OAGB (Table 2).

Table 2
Matched total operative time by procedure

Procedure	n pairs	Robotic median (IQR), min	Laparoscopic median (IQR), min	HL difference (95% exact CI), min
Sleeve gastrectomy	6	155 (139–173)	95 (87–109)	59 (42–82)
OAGB	6	181 (158–207)	112 (97–131)	69 (7–131)
RYGB	15	174 (151–219)	140 (125–155)	34 (13–71)
Sleeve-plus	23	179 (157–202)	118 (108–132)	61 (42–78)
Overall	**50**	**174 (154–206)**	**120 (106–142)**	**54 (45.5–68.5)**

CI, confidence interval; HL, Hodges–Lehmann location-shift estimate; IQR, interquartile range; OAGB, one-anastomosis gastric bypass; PJB, proximal jejunal bypass; RYGB, Roux-en-Y gastric bypass; SADJB, single-anastomosis duodenojejunal bypass; SASJB, single-anastomosis sleeve jejunal bypass. Operative time was measured skin-to-skin. The matched sleeve-plus group comprised 8 SADJB, 8 SASJB, and 7 PJB pairs; outcomes were pooled because subtype sample sizes were small. HL estimates and exact 95% CIs were derived from Walsh averages of the paired robotic-minus-laparoscopic differences. Exact intervals may be wide in small subgroups because of the discrete sampling distribution. Overall paired Wilcoxon signed-rank test: P < 0.001. Procedure-specific estimates are exploratory.

Segmented regression identified a breakpoint at case 31.9 (95% CI 26.4–37.2) (Fig. 2a; Supplementary Table S1). Operative time decreased by 3.2 minutes per case before the breakpoint (95% CI -3.8 to -2.8; P < 0.001). The post-breakpoint slope was − 0.3 minutes per case (95% CI -0.9 to 0.6), and the change in slope was 3.0 minutes per case (95% CI 2.3–3.8; Davies statistic 7.53, P < 0.001). Mean operative time was 208 minutes for cases 1–31 and 154 minutes for cases 32–58; corresponding medians were 203 (IQR 185–232) and 152 (IQR 143–159) minutes (Supplementary Table S2(a)). The exploratory CUSUM peaked at case 26 but remained between 1,082 and 1,111 minutes across cases 22–29, so it did not identify a single transition case (Fig. 2b). Sensitivity analyses produced breakpoints of 31.0 after excluding SG and 34.0 after adjustment for procedure and conversion status.

Complete docking and console times were available for 44 of 58 cases: 25 of 25 in cases 1–25 and 19 of 33 in cases 26–58. Median docking time decreased from 8 minutes (IQR 6–10) to 6 minutes (IQR 5–8) and median console time from 180 minutes (IQR 165–198) to 136 minutes (IQR 125–150) (Supplementary Table S2(b)). These complete-case comparisons of early versus later implementation were descriptive, and their interpretation is limited because component-time data were disproportionately missing later in the series. The eight unmatched robotic patients (mean age 52.3 years, mean BMI 50.1 kg/m²; all primary) sustained no complication, readmission, reoperation, conversion to open surgery, or death. Post hoc mixed-effects estimates were 56 minutes unadjusted and 55 minutes after BMI adjustment (Supplementary Table S3).

Clinical outcomes

Median length of stay was 2 days (IQR 2–3) in both groups. Complications occurred in 2 robotic (4.0%) and 4 laparoscopic patients (8.0%) (paired risk difference − 4.0 percentage points; b = 1/c = 3; exact McNemar P = 0.625), and major complications in 1 (2.0%) and 2 (4.0%) (-2.0 percentage points; b = 1/c = 2; P = 1.000). Readmission occurred in 1 robotic and 2 laparoscopic patients; no conversion to open surgery or mortality occurred (Table 3).

Table 3
Perioperative and 30-day outcomes in the matched cohort

Outcome	Robotic (n = 50)	Laparoscopic (n = 50)	Discordant pairs, b/c	Paired risk difference, pp	Exact McNemar P
Length of stay, median (IQR), days	2 (2–3)	2 (2–3)	—	—	—
Any complication, n (%)	2 (4.0)	4 (8.0)	1/3	-4.0	0.625
Major complication, n (%)	1 (2.0)	2 (4.0)	1/2	-2.0	1.000
Leak, n (%)	0 (0.0)	1 (2.0)	0/1	-2.0	—
Postoperative bleeding, n (%)	1 (2.0)	1 (2.0)	1/1	0.0	—
Readmission within 30 days, n (%)	1 (2.0)	2 (4.0)	0/1	-2.0	—
Reoperation within 30 days, n (%)	0 (0.0)	1 (2.0)	0/1	-2.0	—
Conversion to open surgery, n (%)	0 (0.0)	0 (0.0)	0/0	0.0	—
Mortality, n (%)	0 (0.0)	0 (0.0)	0/0	0.0	—

IQR, interquartile range; pp, percentage points. b denotes pairs in which the outcome occurred after robotic but not laparoscopic surgery; c denotes pairs in which it occurred after laparoscopic but not robotic surgery. Paired risk differences were calculated as (b - c)/50. Major complications were Clavien–Dindo grade III or higher. Exact McNemar tests were performed for any and major complication. Individual component outcomes were reported descriptively because events were sparse, and confidence intervals were not calculated. The study was not designed to establish equivalence. The robotic events were a port-site infection (grade I) and a staple-line bleed requiring endoscopic control (grade IIIa); the laparoscopic events were a surgical-site infection (I), nausea requiring readmission (II), a gastrojejunal leak managed endoscopically (IIIa), and a port-site bleed requiring operative evacuation (IIIb).

The matched cohort was restricted to 50 pairs with clinically measured 12-month weights within the prespecified window. Mean %TWL was 31.8% ± 8.0% robotically and 31.5% ± 7.8% laparoscopically, a

mean paired difference of 0.30 percentage points (95% CI -1.85 to 2.45; paired t test P = 0.78). The standard deviation of the 50 patient-level paired differences was 7.57 percentage points and the within-pair correlation was 0.54. Procedure-specific results are descriptive and were not subjected to formal hypothesis testing (Table 4).

Table 4
Observed 12-month percentage total weight loss in the propensity-matched cohort

Procedure	n pairs	Robotic %TWL, mean ± SD	Laparoscopic %TWL, mean ± SD	Mean paired difference, pp
Sleeve gastrectomy	6	29.3 ± 8.0	29.2 ± 8.2	0.1
OAGB	6	34.0 ± 8.6	33.9 ± 8.5	0.1
RYGB	15	32.5 ± 7.8	32.2 ± 7.6	0.3
Sleeve-plus	23	31.4 ± 8.2	31.0 ± 8.0	0.4
Overall	**50**	**31.8 ± 8.0**	**31.5 ± 7.8**	**0.30 (95% CI -1.85 to 2.45)**

CI, confidence interval; OAGB, one-anastomosis gastric bypass; pp, percentage points; RYGB, Roux-en-Y gastric bypass; SD, standard deviation; %TWL, percentage total weight loss. The matched cohort was restricted to pairs with clinically measured 12-month weights within ± 3 months of the anniversary; missing values were not imputed. The overall comparison used a paired t test. The mean robotic-minus-laparoscopic difference was 0.30 percentage points (95% CI -1.85 to 2.45; P = 0.78), calculated from the 50 patient-level paired differences (SD 7.57 pp; within-pair r = 0.54). Procedure-specific differences are descriptive and were not subjected to formal hypothesis testing. Baseline BMI is reported in Table 1.

Post hoc sex-based analyses are presented in Supplementary Table S4. Operative-time and 12-month %TWL estimates were descriptively similar in male and female pairs, while major complications were too sparse for meaningful sex-specific inference. No formal subgroup or interaction testing was performed.

Discussion

This is the first Malaysian series of robotic MBS. Robotic procedures comprised 58/1,650 operations (3.5%) and were concentrated in gastric bypass, sleeve-plus, and conversion surgery. In the matched cohort, robotic operative time was 54 minutes longer than laparoscopic operative time. The operative-time trajectory changed in the late 20s to early 30s cases, with mean time decreasing from 208 to 154 minutes. Major complications occurred in one robotic and two laparoscopic patients. The 12-month %TWL difference was 0.30 percentage points (95% CI -1.85 to 2.45), without a prespecified equivalence margin.

This series documents selective robotic adoption in a Southeast Asian private-sector program, where platform access and financing differ from regions generating most published evidence. Its concentration

in bypass and conversion surgery, supported by external mentorship, offers a pragmatic example for programs considering selective implementation.

Segmented regression was the primary learning-curve analysis; the CUSUM is exploratory graphical corroboration of the same 58 observations, not independent validation. Both localized the change to the same portion of the sequence, although the CUSUM maximum at case 26 preceded the segmented breakpoint at case 31.9 (95% CI 26.4–37.2), together placing the major efficiency change in approximately the late 20s to early 30s cases. Most of the observed reduction in operative time occurred before the estimated breakpoint, with little evidence of a continuing linear decline thereafter. The estimate lies within the broad range of a recent systematic review [14] and is close to the reduction after 34 robotic RYGB cases in a European program [17]. A single surgeon operated with a consistent core team, reducing potential variation from team composition; the sequence nonetheless spanned several procedures, sites, and two platform generations, and the Si-to-Xi transition occurred after most learning-curve cases, so platform and experience are inseparable.

The persistent time premium accords with previous studies [4–8]. Although the same surgeon performed both approaches, it may reflect the learning curve, calendar time, site, and case complexity rather than the platform alone. Costs were not measured.

Exploratory sex-stratified analyses were descriptively similar across male and female pairs, although subgroup precision was limited, particularly among the 14 male pairs; no formal interaction testing was performed.

Limitations

This retrospective observational study represents one surgeon and one collaborative program. Approach selection was nonrandom, BMI remained imbalanced after matching, and hospital, calendar-time, and other unmeasured effects may have persisted. Eight robotic cases were unmatched, so the comparative estimates apply to the matched subset rather than the entire robotic cohort. Because matching eligibility required a clinically measured 12-month weight, the comparative cohort may underrepresent patients who did not return within the prespecified window. The learning analysis combined several procedures and used chronological case number; it could not separate experience from case mix, intervals between operations, site effects, or the Si-to-Xi transition. The estimated breakpoint should therefore describe this series, not serve as a credentialing threshold. CUSUM was exploratory and not risk-adjusted, while component times were missing in 14 later cases. Only three pairs were discordant for major complications, and sex-stratified analyses were limited by the smaller number of male pairs and sparse events; no equivalence margin was prespecified; comparative safety was not established. Follow-up was limited to 12 months, and costs and ergonomic outcomes were not measured.

Conclusion

In this Malaysian single-surgeon series conducted across three hospitals, robotic MBS was introduced selectively within an established laparoscopic program through structured international mentorship. The single-surgeon operative-time trajectory changed at approximately 30 cases, but robotic procedures remained 54 minutes longer than matched laparoscopic procedures. Major complications were sparse, and the 12-month %TWL estimate was 0.30 percentage points (95% CI -1.85 to 2.45), without a prespecified equivalence margin. These findings describe one implementation pathway and establish neither robotic superiority nor a case for routine substitution.

Declarations

Conflict of Interest:

The authors declare no conflict of interest.

Ethical Approval:

The study received approval from the relevant national research ethics committee; identifying details and the approval number have been withheld for double-anonymous review. The approval covered all participating hospitals. The study was conducted in accordance with the Declaration of Helsinki and its later amendments.

Informed Consent:

The ethics committee waived individual informed consent because this was a retrospective analysis of de-identified clinical data.

Use of Artificial Intelligence

OpenAI ChatGPT was used solely to improve language, grammar, readability, and formatting. The authors reviewed and approved all changes and take full responsibility for the final content.

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Author Contribution

T.G contributed to conceptualization, methodology, surgicalinvestigation, supervision, interpretation, and manuscript drafting and revision. L.S.Ycontributed to data curation, methodology, formal analysis,

interpretation, and manuscriptdrafting and revision. Both authors approved the final manuscript and accept responsibility forthe integrity of the work.

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Data Availability:

De-identified data supporting the findings are available from the corresponding author upon reasonable request, subject to institutional ethics and data-sharing approval.

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Figures

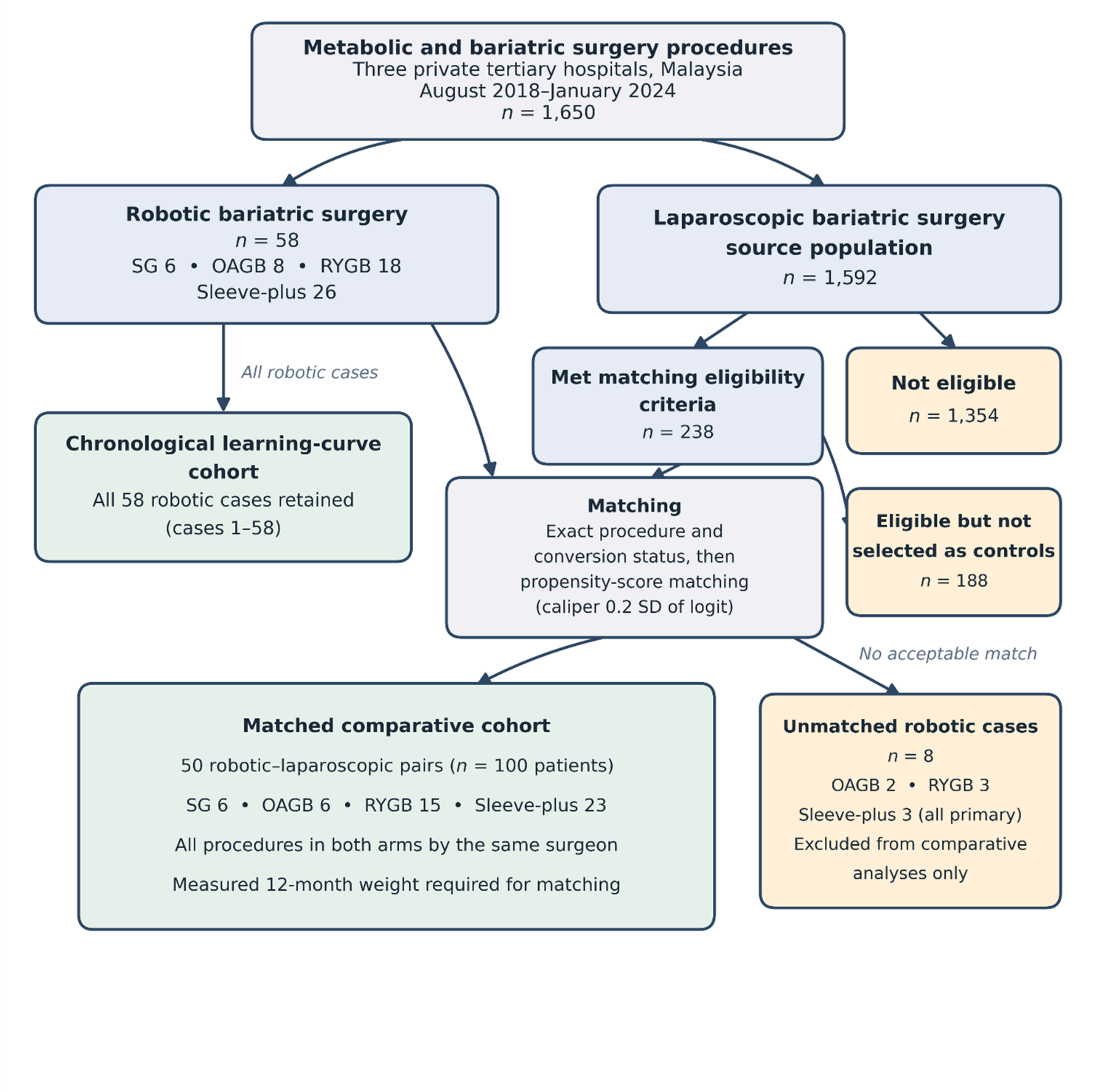
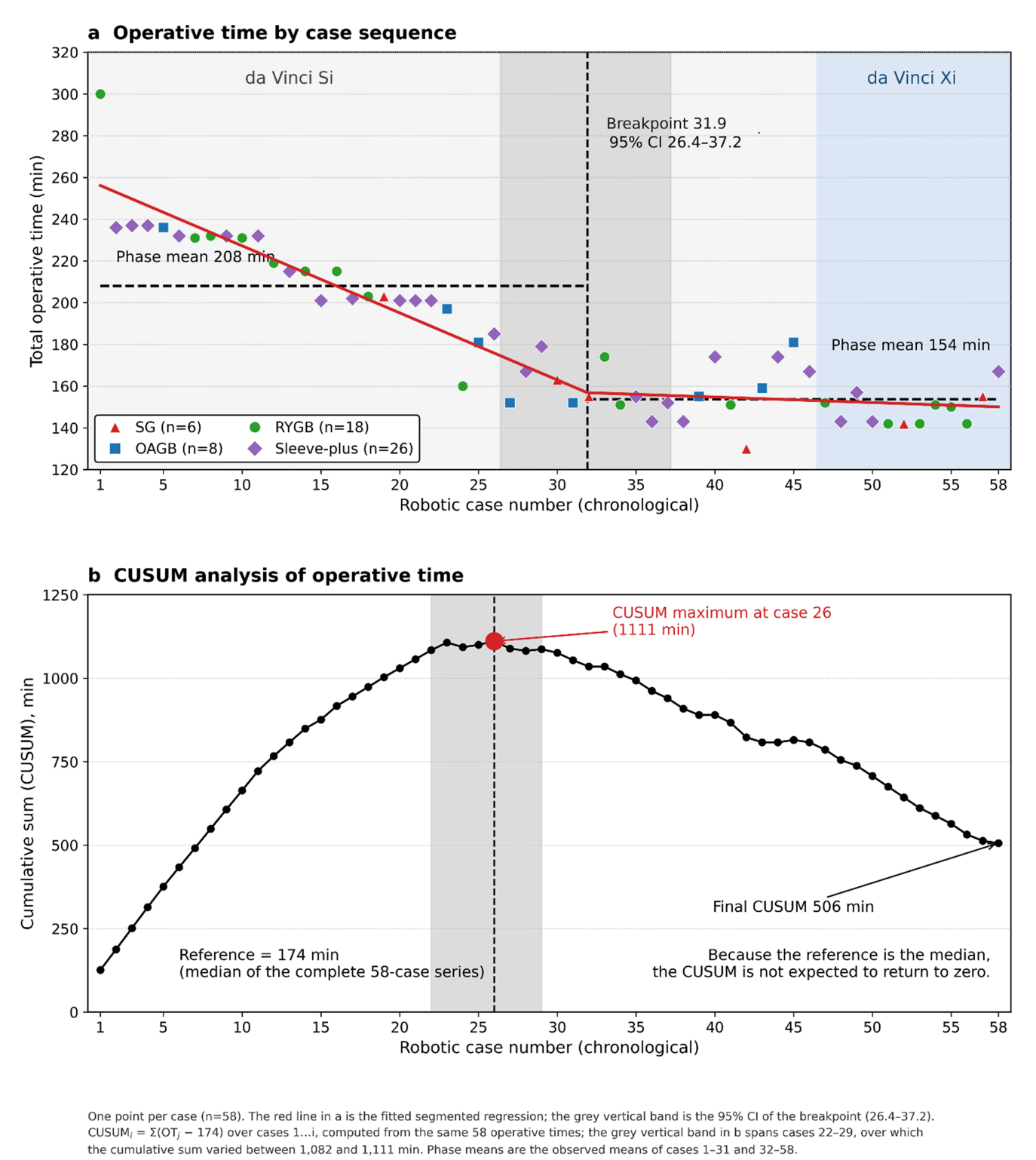


Figure 1

Participant flow. Of 1,650 metabolic and bariatric procedures performed between August 2018 and January 2024, 58 were robotic and all entered the chronological learning-curve cohort. Of 1,592 laparoscopic procedures, 238 met the matching eligibility criteria: a procedure and conversion category represented in the robotic cohort, complete baseline matching variables, and a clinically measured 12-month weight within ±3 months. Fifty were selected as matched controls and 188 eligible procedures were not selected. Fifty robotic cases were matched 1:1 by exact procedure type and conversion status

plus propensity-score nearest-neighbor matching; eight robotic cases without an acceptable match were excluded from comparative analyses only. All procedures in both arms were performed by the same surgeon. OAGB, one-anastomosis gastric bypass; RYGB, Roux-en-Y gastric bypass; SD, standard deviation; SG, sleeve gastrectomy.



One point per case (n=58). The red line in a is the fitted segmented regression; the grey vertical band is the 95% CI of the breakpoint (26.4–37.2). $CUSUM_i = \Sigma(OT_j - 174)$ over cases 1…i, computed from the same 58 operative times; the grey vertical band in b spans cases 22–29, over which the cumulative sum varied between 1,082 and 1,111 min. Phase means are the observed means of cases 1–31 and 32–58.

Figure 2

Operative-time learning curve across the 58-case robotic series. (a) Total operative time for each consecutive robotic case, with procedures distinguished by marker shape and color. The solid red line is the fitted segmented regression. The dashed vertical line marks the breakpoint at case 31.9 and the grey vertical band its 95% confidence interval (26.4–37.2). Horizontal dashed lines indicate the observed phase means of 208 minutes for cases 1–31 and 154 minutes for cases 32–58. Background shading indicates the da Vinci Si and Xi platform eras. (b) Cumulative sum of operative time using 174 minutes, the median of the complete 58-case cohort, as the reference. The dashed vertical line marks the maximum at case 26 (1,111 minutes); the shaded vertical band spans cases 22–29, over which the cumulative sum varied between 1,082 and 1,111 minutes. The final CUSUM was 506 minutes. Because the reference was the median rather than the mean, the curve was not expected to return to zero. CUSUM, cumulative sum; OAGB, one-anastomosis gastric bypass; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

Supplementary Files

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- OBSUSTROBECohortChecklistFinalVetted.docx
- OBSUSupplementaryFileFinalChecked1.docx