

Robotic-Assisted versus Navigated and Freehand Posterior Lumbar Fusion: A Retrospective Propensity-Weighted Cohort Study with Elderly, Obese, and Multilevel Subgroup Analyses

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Abstract

Purpose

To evaluate perioperative and postoperative outcomes following robotic-assisted (RA), navigated, and freehand posterior lumbar fusion across degenerative, elderly (≥ 70 years), obese ($\text{BMI} \geq 30 \text{ kg/m}^2$), and multilevel (≥ 2 levels) cohorts.

Methods

Retrospective two-centre cohort study of 347 patients undergoing posterior lumbar fusion (April 2019–June 2023). Freehand and navigated cases were drawn from a public tertiary referral centre; RA cases from a private hospital using the ExcelsiusGPS™ (Globus Medical). Multinomial propensity scores and stabilised inverse probability of treatment weights (IPTW) were derived within each subgroup. Binary outcomes were assessed using weighted logistic regression and continuous outcomes using weighted generalised linear models with robust standard errors.

Results

RA was associated with shorter operating time, lower blood loss, shorter length of stay, and lower complication odds versus both comparators across all subgroups. In the degenerative cohort ($n = 261$), RA was associated with significantly lower odds of any complication at 6 months, medical complications, and dural tear. In elderly patients ($n = 112$), RA was associated with lower complication odds and shorter length of stay; estimates should be interpreted cautiously given small effective sample sizes. In obese patients ($n = 140$), RA was associated with lower overall complication odds and fewer revisions than navigation. In the multilevel cohort ($n = 193$), perioperative advantages were consistent but complication comparisons did not reach statistical significance.

Conclusions

RA lumbar fusion was associated with consistent perioperative advantages across all subgroups; however, residual confounding by institutional setting and surgical approach means these advantages should be attributed to the joint effect of minimally invasive fusion enabled by RA.

Introduction

Robotic-assisted (RA) lumbar fusion has steadily gained popularity since the SpineAssist™ first received FDA approval in 2004[1]. Its indications include degenerative disc disease, trauma, tumour, and deformity correction[2]. Today, numerous systems are available that incorporate native intraoperative navigation alongside dexterous instrumentation, increasing precision and reducing tracking error[3, 4]. RA also

offers ergonomic benefits for surgeons, reducing physical strain and significantly lowering radiation exposure[5].

Recent evidence suggests a number of advantages of RA over freehand and navigated pedicle screw placement. RA may facilitate the insertion of larger pedicle screws through smaller incisions while reducing the risk of neural injury[6]. By limiting the need for extensive muscle retraction[7], it may also reduce paraspinal ischaemia, postoperative pain and subsequent muscle degeneration. Compared with open techniques, RA minimally invasive fusion has been associated with shorter hospital stays and improved theatre efficiency without an increase in complications[8]. In addition, biomechanical evidence suggests that superior facet joint violation (FJV) during pedicle screw placement increases load transmission across the facet complex, providing a plausible mechanism for adjacent segment degeneration[9]. Because RA appears to reduce the incidence of superior FJV, it may have possible implications for long-term revision risk [9].

However, the patients in whom these advantages may be most clinically relevant remain poorly studied. No published analysis has specifically examined RA lumbar fusion in elderly, obese or multilevel cohorts. These groups present distinct technical and perioperative challenges, including osteoporosis, frailty, impaired mobility, deep operating corridors, greater comorbidity burden, prolonged operating time and delayed recovery[10]. RA may be particularly attractive in elderly patients, in whom minimising tissue trauma could facilitate earlier mobilisation and recovery. In patients with obesity, RA may help overcome the visualisation difficulties imposed by deep soft tissue corridors. In multilevel fusion, the cumulative risk of clinically significant screw malposition increases with each additional screw placed, which suggests the accuracy advantages of RA may be particularly pronounced when long constructs are required.

The purpose of this manuscript is to examine the potential advantages of robotic-assisted lumbar fusion in elderly, obese, and multilevel patients, and to explore whether these cohorts may derive particular benefit from improved screw placement accuracy and less invasive surgery compared with freehand and navigated fusion techniques.

Methods

Study design, setting, and reporting

This retrospective cohort study was performed with institutional review board approval and is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines[1]. Patients undergoing posterior lumbar fusion with pedicle screw instrumentation between April 2019 and June 2023 were identified from two institutional settings: freehand and navigated cases were drawn from a public tertiary referral centre, while RA cases were drawn from a private hospital. RA screw placement was performed using the ExcelsiusGPS™ (Globus Medical, Audubon, PA, USA).

Participants and eligibility

Patients undergoing posterior lumbar fusion (with or without interbody cage placement and with or without direct decompression) were eligible. Patients with neoplastic, and infectious indications were excluded as were polytrauma patients. A minimum follow-up of at least six weeks was required for inclusion. In this text, minimally invasive surgery describes screws inserted percutaneously or via a paramedian transfascial (Wiltse) approach with decompression (if applicable) performed using tubular retractors.

Data sources and variables

Demographic, perioperative, and postoperative variables were extracted from local paper and electronic records using a standardised collection template. Extracted variables included: age, sex, height, weight, BMI, smoking status, comorbidities (including hypertension, ischaemic heart disease, diabetes, and chronic obstructive pulmonary disease), procedure characteristics (number of levels operated, upper instrumented vertebra, use of minimally invasive technique, and cage use), and complications, reoperation, length of stay.

Outcomes

Outcomes were perioperative and early postoperative endpoints captured during the index admission and follow-up to 6 months. The primary safety endpoint in the degenerative cohort was a composite of any complication within 6 months, defined as the occurrence of one or more recorded medical or surgical complications during this period, excluding adjacent segment disease and restenosis. Secondary outcomes included: length of stay (days), estimated blood loss (mL), operating time (minutes), revision surgery within 6 months, any medical complication (composite), dural tear, and symptomatic screw malposition.

Data synthesis and statistical analysis

Unweighted descriptive statistics were first generated for the full cohort to characterise baseline differences and case mix across freehand, navigated, and RA techniques. Clinically motivated subgroup analyses were then performed in relevant populations:

1. Degenerative disease cohort
2. Age > 70 years
3. BMI > 30 kg/m²
4. Multilevel fusion (Two or more operated levels)

For each subgroup, treatment effects were estimated using propensity score weighting followed by weighted regression.

Descriptive and unadjusted comparisons

Continuous variables were summarised as mean and standard deviation. Categorical variables were summarised as n (%). For three-group unadjusted comparisons, Welch's ANOVA was used. Categorical variables were compared using Fisher–Freeman–Halton tests of independence. For binary outcomes with sparse events (no study arm had 10 or more events), multivariable modelling was not performed due to limited power and risk of unstable estimates.

Propensity score estimation and weighting

Within each cohort (e.g., degenerative disease), propensity scores for receipt of freehand, navigated, or RA techniques were estimated using a multinomial logistic regression model. Baseline covariates were entered as predictors and included available demographic and clinical variables, along with operative descriptors that plausibly influenced treatment assignment: Age, BMI, gender, extent of surgery, upper instrumented level, smoking status, hypertension, ischaemic heart disease, diabetes, chronic obstructive pulmonary disease, osteoporosis (clinical diagnosis), minimally invasive screw placement, use of interbody cage and index versus revision procedure.

Predicted class probabilities from the multinomial model were used to derive stabilised inverse probability of treatment weights (IPTW), calculated as the marginal probability of the observed treatment divided by the individual's estimated propensity for the received treatment. Stabilised weights were rescaled to have a mean of 1. Effective sample sizes were quantified using Kish's approximation overall and within each treatment arm to assess the impact of weighting.

Outcomes were analysed using weighted generalised linear models with stabilised IPTW applied as frequency weights. Robust (HC1) standard errors were used to account for heteroskedasticity under weighting. Covariates with residual imbalance after weighting ($SMD > 0.2$) were included in regression models unless otherwise stated.

For binary endpoints (e.g., any complication), weighted logistic regression was used and results were expressed as odds ratios with 95% confidence intervals. For continuous outcomes, generalised linear models were used with results reported in interpretable units (mean differences for Gaussian models and ratio-of-means for gamma-log models).

Software

All analyses were performed using Python. Propensity score modelling used scikit-learn pipelines for preprocessing and multinomial logistic regression. Weighted outcome models were implemented using

statsmodels. Statistical tests used SciPy and statsmodels utilities.

Results

Across all included patients ($n = 347$), significant between-technique differences were present in age, sex distribution, number of operated levels, use of minimally invasive technique, use of an interbody cage, proportion of trauma, ischaemic heart disease and chronic obstructive pulmonary disease and the distribution of upper instrumented vertebra (UIV) (Table 1). Notably, no robotic-assisted cases were undertaken for trauma, whereas trauma accounted for 40.5% of freehand and 50.5% of navigated cases.

Table 1
Baseline Characteristics of All Included Patients

N	Freehand	Nav	Robotic	P
	84	103	160	
Age	57.28 ± 18.55	57.89 ± 16.84	63.66 ± 12.30	0.028
BMI	28.34 ± 5.22	29.35 ± 6.89	29.92 ± 5.02	0.096
Male	44 (52.38%)	46 (44.66%)	58 (36.25%)	0.047
Smoker	33 (39.29%)	48 (46.60%)	55 (34.38%)	0.140
Levels	2.45 ± 1.25	2.39 ± 1.29	1.37 ± 0.69	< 0.001
Index Procedure	66 (79.52%)	78 (75.73%)	117 (73.12%)	0.545
MIS	9 (10.71%)	30 (29.13%)	137 (85.62%)	< 0.001
Cage	7 (10.77%)	20 (20.62%)	56 (35.00%)	< 0.001
Trauma	34 (40.48%)	52 (50.49%)	0 (0.00%)	< 0.001
HTN	34 (40.48%)	43 (41.75%)	52 (32.50%)	0.245
IHD	15 (17.86%)	10 (9.71%)	12 (7.50%)	0.042
DM	9 (10.71%)	5 (4.85%)	9 (5.62%)	0.218
COPD	4 (4.76%)	8 (7.77%)	2 (1.25%)	0.030
Osteoporosis	3 (3.57%)	9 (8.74%)	8 (5.00%)	0.274
Upper Instrumented Level				
T11	11 (13.25%)	15 (14.56%)	0 (0.00%)	< 0.001
T12	10 (12.05%)	15 (14.56%)	0 (0.00%)	
L1	6 (7.23%)	10 (9.71%)	2 (1.27%)	
L2	19 (22.89%)	15 (14.56%)	6 (3.80%)	
L3	15 (18.07%)	25 (24.27%)	29 (18.35%)	
L4	21 (25.30%)	17 (16.50%)	80 (50.63%)	
L5	1 (1.20%)	6 (5.83%)	41 (25.95%)	
Significant differences shown in bold				
MIS – Minimally invasive surgery				

Outcomes the in Degenerative Cohort

The degenerative cohort comprised 261 patients (freehand n = 50, navigation n = 51, robotic-assisted n = 160). Before weighting, substantial imbalance was evident for operative extent (number of levels), MIS use, cage use, hypertension and other comorbidities, and UIV distribution. After IPTW, balance improved for most baseline variables; however, some residual imbalance persisted, particularly for MIS use and number of operated levels. The ESS after weighting was 40.4 (freehand), 28.8 (navigation) and 104.4 (RA).

Navigation was associated with longer operating time than freehand (+ 32.4 min; p = 0.025) but showed no clear differences in blood loss, length of stay, complications, infection, or revision. RA was associated with shorter operating time, lower blood loss, and shorter length of stay than both freehand and navigation, and with substantially lower odds of overall complications, medical complications, and dural tear.

Outcomes in the Elderly Cohort (≥ 70 years)

Cohort: n = 112 (freehand 28; navigation 24; RA 60). After IPTW, residual imbalance remained for several variables. ESS: freehand 25.1; navigation 18.3; RA 49.2.

After weighting, operating time did not differ meaningfully between RA and freehand. Compared with both freehand and navigated surgery, RA was consistently associated with lower blood loss, shorter length of stay, and markedly lower odds of overall and medical complications. Dural tears were less frequent with RA in unadjusted data (p = 0.004), but these were not modelled.

Outcomes in the Obese Cohorts (≥ 30 BMI)

Cohort: n = 140 (freehand 29; navigation 38; RA 73). ESS after IPTW: freehand 19.2; navigation 24.8; RA 40.1.

Navigation was associated with longer operating time than freehand (+ 40.6 min; p = 0.022) without clear differences in blood loss or length of stay. RA was faster than navigation (-45.0 min; p < 0.001) but not significantly faster than freehand, and was associated with lower blood loss, shorter length of stay, and lower odds of overall and medical complications. RA was also associated with fewer dural tears than navigation (OR 0.13; p = 0.007). Revisions were less frequent with RA than navigation on unadjusted Cox analysis (HR 0.22; p = 0.004).

Outcomes after Multilevel RA, Navigated and Freehand Fusion

Cohort: n = 193 (freehand 68; navigation 78; RA 47). ESS after IPTW: freehand 58.5; navigation 52.9; RA 35.5

After weighting, navigation was associated with longer operating time than freehand (+ 18.4 min; $p = 0.046$) but shorter length of stay (mean ratio 0.70; $p = 0.037$). RA was associated with shorter operating time, substantially lower blood loss, and shorter length of stay than both freehand and navigation. Complication rates numerically favoured RA, but adjusted comparisons were not statistically definitive.

Discussion

Computer-assisted screw placement, whether by navigation or RA, has become commonplace in contemporary spine surgery, largely because this technology improves pedicle cannulation, reduces the rate of high-grade breach, and facilitates minimally invasive surgery. Large administrative datasets and temporal analyses suggest that the uptake of computer-assistance has increased over the last decade [11]. However, significant disparities remain between hospitals and justifications due to varying financial and cultural incentives. This work examines perioperative and early postoperative outcomes following freehand, navigated and RA posterior lumbar fusion across a primary degenerative cohort and clinically relevant subgroups, using propensity scoring weighting and multivariable outcome models to mitigate measured confounding.

Within the degenerative cohort ($n = 261$), RA was associated with materially shorter operating time than both freehand and navigation (adjusted – 29min vs freehand and – 61.4min versus navigation), substantially lower estimated blood loss (adjusted – 368mL vs freehand and – 250mL vs navigation) and markedly shorter length of stay (ratio-of-means 0.5 vs freehand and 0.44 vs navigation). RA was also associated with substantially lower odds of any complication within 6 months (OR 0.14 vs freehand; OR 0.21 vs navigation), any medical complication (OR 0.04 vs freehand, OR 0.098 vs navigation) and dural tear (OR 0.20 vs freehand; OR 0.14 vs navigation). These are larger differences than are commonly attributed to robotic assistance alone in most series published in the broader literature.

Shahi et al. performed a retrospective comparison of RA vs Nav MIS TLIF finding no significant difference between groups when comparing total operating room time (144.2 ± 27.6 vs 139 ± 34.2 min, RA vs Nav, $p = 0.23$), blood loss (67.5 ± 78.2 vs 55.6 ± 74.3 mL, RA vs Nav, $p = 0.20$), length of stay (26.7 ± 4.5 vs 27.2 ± 6.3 hours, RA vs Nav, $p = 0.46$), screw related complications or overall revision rate (5.5% vs 10.3%, RA vs Nav, $p = 0.14$) in a 278 patient degenerative cohort with at least one year follow up. Notably, medical complications were not reported[2]. Health et al. published a 100-patient cohort comparison of RA and navigated MIS TLIF with similar conclusions[3]. Conversely, the prospective, multicentre, partially randomised MIS-Refresh trial[4] compared 374 RA MIS posterior fusions versus 111 freehand patients, and found significantly fewer surgical and wound-related complications in the robotic group at two years' follow-up (10.4% vs 35.1%, $p < 0.001$) with no difference in skin-to-skin time. This trial was, however, funded by Mazor, the manufacturer of the investigated device.

The growing elderly cohort contains a significant burden of degenerative disease and is more easily injured after trauma, thus frequently presenting in need of fusion. Old patients are also necessarily vulnerable to the systemic insult of surgery and the downstream consequences of blood loss, bed rest,

infection, etc. It stands to reason that MIS fusion may disproportionately benefit this group as postoperative recovery is hastened and the posterior myofascial complex is spared, likely promoting long-term preservation of function. Similarly, these patients are technically difficult to operate due to degenerative deformity, poor bone stock, adverse pedicle remodelling and arthrosed facet joints and ligamentous calcification. Thus, modern technologies such as robotic assistance may also offer additional benefits. It is known that octogenarians suffer significantly more adverse events and have higher mortality after fusion than younger patients[5]. This remains true after MIS fusion [6]. However, to our knowledge, only two published investigations directly compare the results of MIS versus open fusion in this group[7, 8], and none compare RA versus navigated and freehand techniques.

In this investigation, patients 70 years or older ($n = 112$) also suffered markedly lower blood loss (adjusted – 260mL vs freehand, -215mL vs navigation) and markedly shorter length of stay (ratio 0.25 vs freehand; 0.23 vs navigation). The very low adjusted odds ratio of all complications ($\sim$ OR 0.01) should be interpreted cautiously in light of baseline differences between cohorts in terms of both measured and unmeasured confounders, and a low effective sample size after weighting; this estimate directionally supports the hypothesis that RA MIS fusion reduces medical and surgical morbidity in older patients.

In the present obese subgroup analysis, RA was associated with significantly shorter length of stay (0.56x freehand; 0.49 vs navigation) and lower odds of both any complication (OR 0.26 vs freehand, OR 0.16 vs navigation) and medical complications (OR 0.09 vs freehand; OR 0.11 vs navigation). Revision surgery was also less frequent than navigation on unadjusted time-to-event modelling (HR 0.22). RA surgery was significantly quicker than navigated fusion and resulted in less intraoperative blood loss than both freehand and navigated surgery. These results encourage the interpretation that RA enables obese patients to benefit from the reduced systemic insult from MIS without penalty from instrumentation-related complications.

In the multilevel subgroup (≥ 2 operated levels; $n = 193$), compared with freehand, RA was associated with a 31.2-minute reduction in operating time (95% CI – 57.3 to – 5.1) and 398 mL lower blood loss (95% CI – 585.5 to – 211.2). Compared with navigation, RA was 49.5 minutes faster (95% CI – 72.3 to – 26.9) with 270 mL less blood loss (95% CI – 394.8 to – 145.5). Length of stay also favoured RA (0.31x vs freehand; 0.45x vs navigation). In contrast, complication estimates in multilevel cases directionally favoured RA but were not statistically significant.

The chance of a given patient experiencing at least one clinically relevant breach during screw placement increases with each additional level instrumented. Level specific comparison of navigated and RA fusion suggest a per screw risk of significant misplacement (≥ 4 mm lateral breach, ≥ 2 mm inferior/medial breach, facet or endplate violation into the superior unfused level) of 1.43% (95%CI 0.73% – 2.8%) with robotic assistance and 6.14% (95%CI 4.5% – 8.3%) with navigation[12]. Assuming breaches are independent conditional on case difficulty, this implies patients undergoing single-level navigated fusion with four screws have ~ 17.0 – 29.2% risk of one or more unacceptable screw placements escalating to $\sim 37.2\%$ – 57.8% if all lumbar levels are instrumented. RA has been criticised in literature

due to, on a per-screw basis, only modest reductions in the rate of neurological complications and significant breaches. Figure 5 shows how this difference materially escalates with the extent of fusion when the patient is the unit of analysis rather than the screw.

Lee et al.[13] performed the first comparison of RA and freehand in multilevel fusions performed for various indications, indicating degenerative scoliosis and multilevel spondylosis. After propensity score matching, there was no significant difference in terms of rates of motor or sensory deficit, implant failure or revision rate at two years' follow-up. Of note, all procedures were performed open, which improves the ability to place screws freehand and negates the principal benefits of RA. An RCT assessing RA in degenerative scoliosis is being planned[14]; however, at the time of writing, there is no evidence to support any of RA, navigation or freehand surgery in the multilevel fusion cohort more broadly.

This study has a number of limitations. First, participants were recruited at two sites which have different patient demographics. Outcomes in private patients receiving RA fusion are likely biased in favour of RA due to greater household wealth, healthier lifestyles and likely fewer comorbid conditions. Propensity weighting and regression models were used to estimate the effect of RA conditional on measured differences in age, BMI and major pre-existing conditions however, residual bias is expected.

Differing incentive structures between the two sites likely also influence these results. RA was found to be consistently faster than freehand and navigated surgery. Although skin-to-skin time was measured in all cases, in the private sector, operator income is directly linked to theatre throughput, which biases this result in favour of RA. Similar incentives to discharge patients after surgery likely also contribute to very large reductions in length of stay seen with RA.

All medical and surgical complications recorded either via the electronic health record or the patient's paper chart were included in the analysis for each arm; however, the sites are staffed by different ward clinicians who likely vary in their thresholds for investigation, documentation, clinical diagnosis and instigation of treatment for minor conditions such as delirium.

Approximately half of the cases in the freehand and navigated surgical arms were performed for traumatic indications, and although polytrauma was excluded, this again confounds subgroup analyses of the elderly, obese and multilevel surgery, however, with an unclear direction of bias. The trauma group are plausibly younger, more functional and less comorbid at baseline, although the converse could also be argued due to the role of frailty and invalidity in precipitating both falls and injury after minor trauma.

Robust statistical methods were used to address the measured confounders listed above; however, after propensity weighting, in every case, significant covariate imbalance remained. Regression models were used to counteract this; however, the effective sample size limits the precision of our estimates, and residual bias remains. There were large differences in the utilisation of MIS between techniques, and our estimates likely partially reflect the combined effect of RA and MIS in a private setting versus Open surgery performed with navigation or freehand in a public setting.

Outcomes at long-term follow-up likely remain the most informative and interesting, given the hypothesised roles of FJV and iatrogenic injury to muscle injury to long-term spine health and function; however, this was not available in the current dataset.

Conclusion

In this retrospective two-centre cohort of 347 posterior lumbar fusions, RA pedicle screw placement was associated with shorter operating time, markedly lower estimated blood loss, shorter length of stay, and fewer recorded medical and overall complications at 6 months compared with freehand and navigated techniques, with similar findings in degenerative disease and in elderly, obese and multilevel subgroups after propensity-score weighting. However, technique selection was strongly confounded by institutional setting and surgical approach, with substantial non-overlap in minimally invasive utilisation and operative extent persisting after weighting, limiting causal attribution of these effects to robotics alone. The observed effect sizes, particularly for length of stay and complications, are therefore most consistent with a combined influence of minimally invasive exposure, perioperative care pathways, and differences in patient selection and event ascertainment between sites.

Declarations

Author Contribution

C.M. wrote the manuscript. D.S. compiled the data. A.S., S.K., and J.M. contributed to data collection and figures. S.D. and J.B. supervised the project from inception. All authors reviewed and approved the final manuscript.

References

1. Von Elm E, Altman DG, Egger M et al (2014) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Int J Surg* 12:1495–1499
2. Shahi P, Subramanian T, Araghi K et al (2023) Comparison of robotics and navigation for clinical outcomes after minimally invasive lumbar fusion. *Spine* 48(19):E297–E305
3. Heath DC, Chang H-K, Chang C-C et al (2024) Comparison between robot-assisted and navigation-guided minimally invasive transforaminal lumbar interbody fusion: a multicenter study. *Neurosurg Focus* 57(6):E12
4. Good CR, Orosz L, Schroerlucke SR et al (2021) Complications and revision rates in minimally invasive robotic-guided versus fluoroscopic-guided spinal fusions: the MIS ReFRESH prospective comparative study. *Spine* 46:1661–1668
5. Kuo CC, Royse KE, Prentice HA, Harris JE, Guppy KH (2022) Are octogenarians at higher risk of complications after elective lumbar spinal fusion surgery? Analysis of a cohort of 7880 patients

- from the Kaiser Permanente Spine Registry. *Spine* 47:1719–1727
6. Huang J, Rabin EE, Stricsek GP, Swong KN (2021) Outcomes and complications of minimally invasive transforaminal lumbar interbody fusion in the elderly: a systematic review and meta-analysis. *J Neurosurg Spine* 36:741–752
 7. Rodgers WB, Gerber EJ, Rodgers JA (2010) Lumbar fusion in octogenarians: the promise of minimally invasive surgery. *Spine* 35:S355–S360
 8. Yolcu YU, Helal A, Alexander AY et al (2021) Minimally invasive versus open surgery for degenerative spine disorders for elderly patients: experiences from a single institution. *World Neurosurg* 146:e1262–e1269
 9. McNamee C, McDonnell JM, Kelly D, Marland H, Darwish S, Butler JS (2025) Superior facet joint violation after lumbar pedicle screw placement: a scoping review. *Asian Spine J* 19:1032–1044
 10. McDonnell JM, Darwish S, Butler JS, Buckley CT (2025) The role of adipokines in spinal disease: a narrative review. *JOR Spine* 8:e70083
 11. Pando A, Hanna G, Goldstein I (2023) Robotic assistance in lumbar fusion surgery: trends and patterns from 2016–2019. *Eur Spine J* 32:1966–1972
 12. Asada T, Subramanian T, Simon CZ et al (2024) Level-specific comparison of 3D navigated and robotic arm-guided screw placement: an accuracy assessment of 1210 pedicle screws in lumbar surgery. *Spine J* 24:1872–1880
 13. Lee NJ, Boddapati V, Mathew J et al (2021) Does robot-assisted spine surgery for multi-level lumbar fusion achieve better patient-reported outcomes than free-hand techniques? *Interdiscip Neurosurg* 25:101214
 14. Hanks K (2023) Spinal fusion for adult degenerative scoliosis: RCT of robot-assisted versus navigation guidance. [ClinicalTrials.gov registration NCT05478395](https://www.clinicaltrials.gov/ct2/show/study/NCT05478395)

Figures

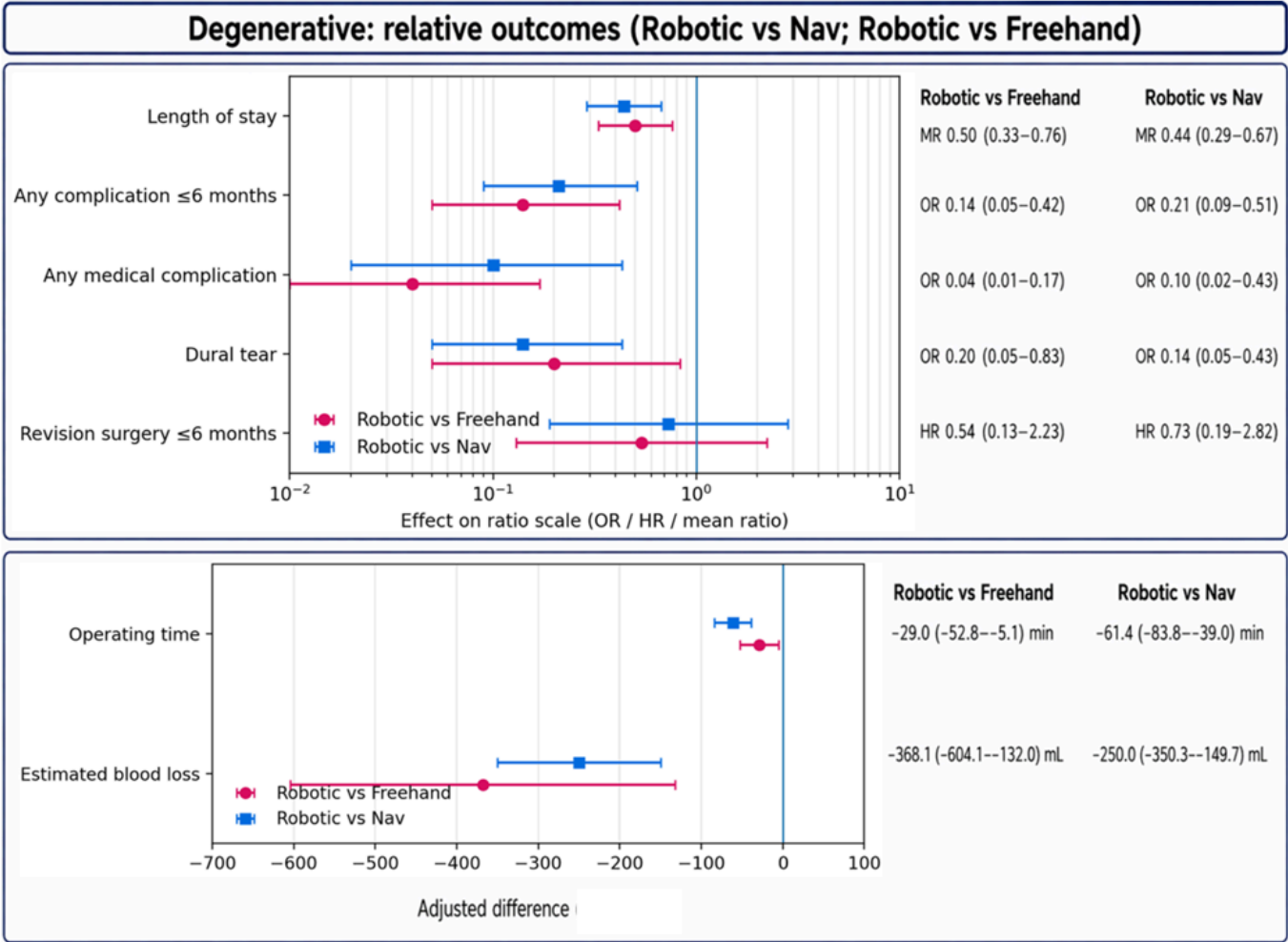


Figure 1

Multivariate Outcomes in Degenerative Cohort

Age >70 (Elderly): relative outcomes (Robotic vs Nav; Robotic vs Freehand)

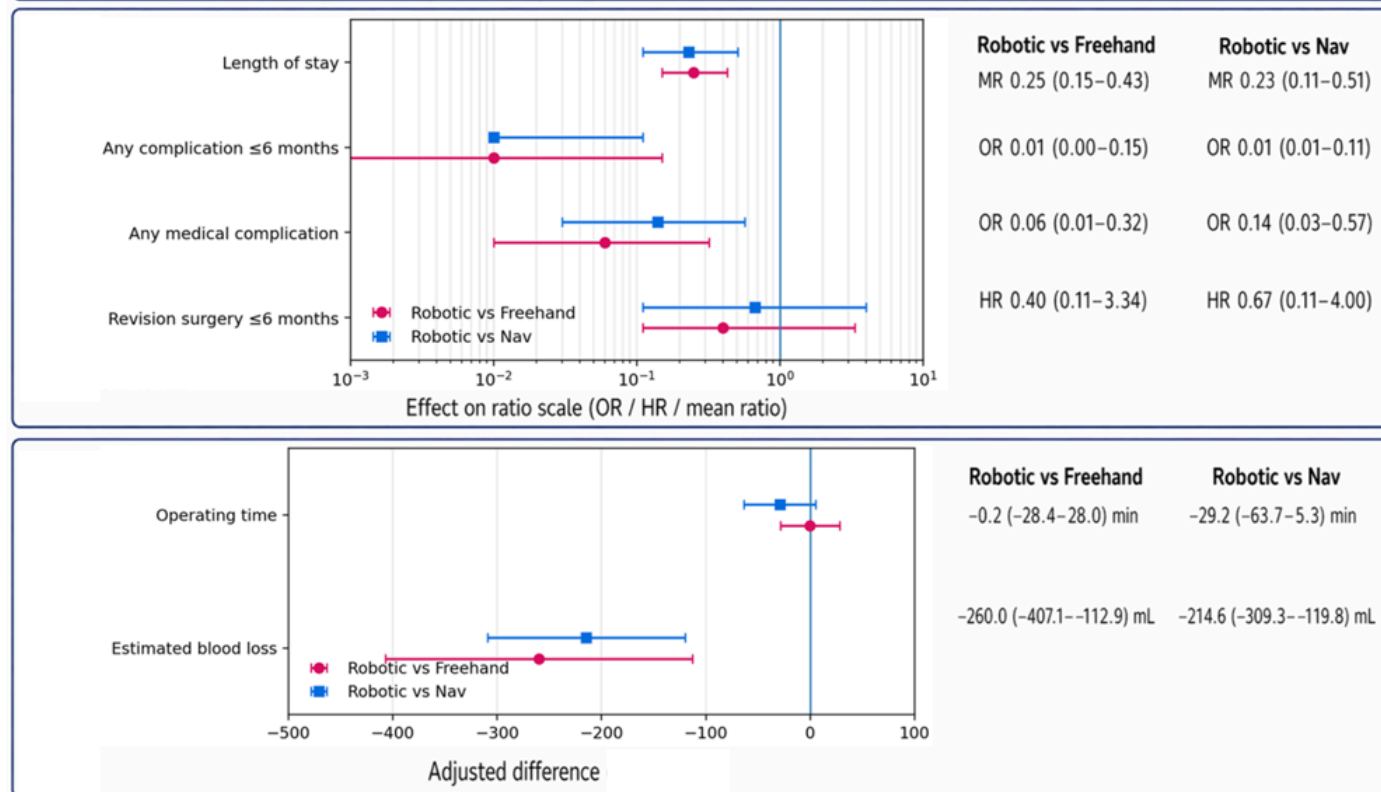


Figure 2

Multivariate Outcomes in Elderly Cohort

BMI >30 (Obese): relative outcomes (Robotic vs Nav; Robotic vs Freehand)

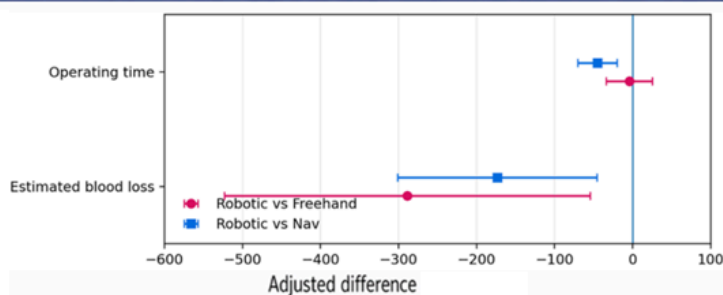
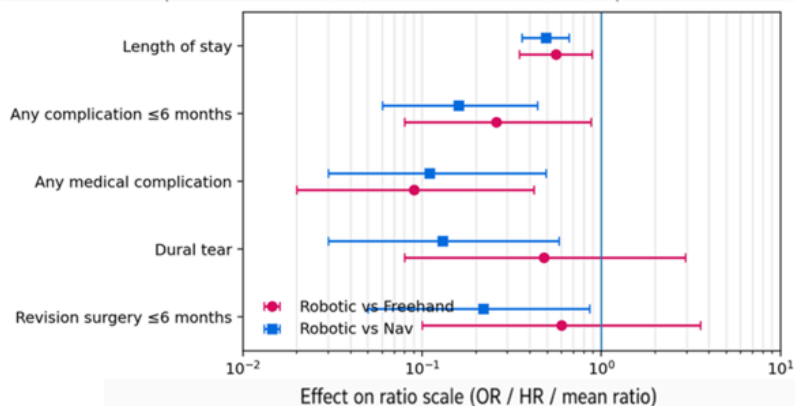


Figure 3

Multivariate Outcomes in Obese Cohort

Multilevel (all indications): relative outcomes (Robotic vs Nav; Robotic vs Freehand)

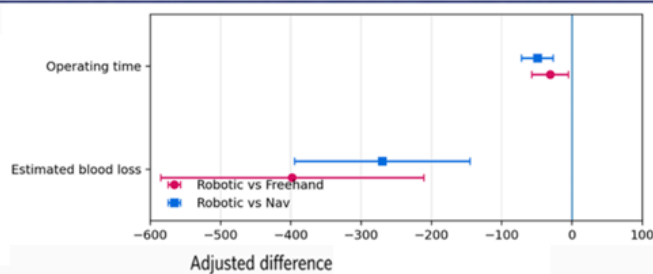
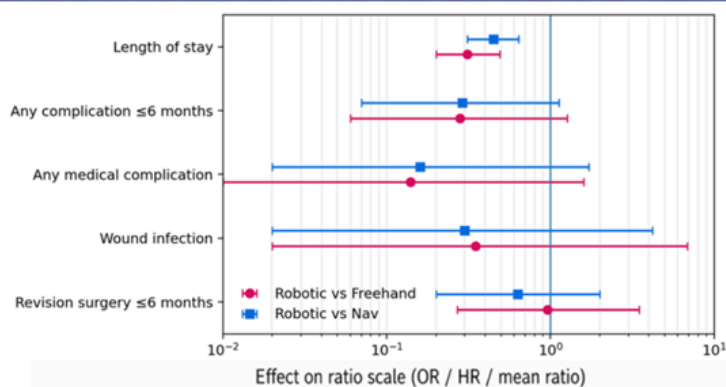


Figure 4

Multivariate Outcomes in Multilevel Fusion

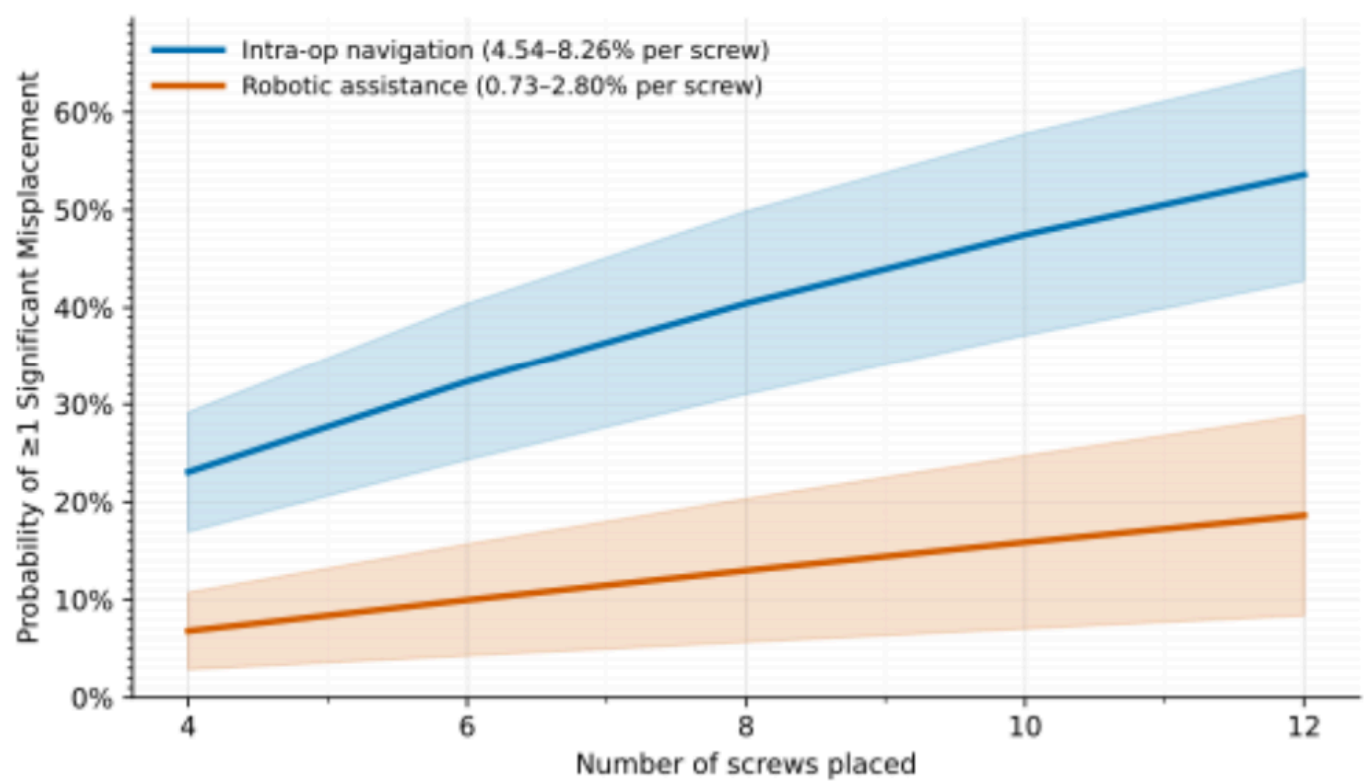


Figure 5

Probability of Significant Misplacement vs Number of Screws Placed: Event rates taken from Asada et al.[12]

Supplementary Files

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