Minimally Invasive Surgical Technologies: Optimizing Operating Room Efficiency

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Abstract
Minimizing tissue trauma, patient recovery, and enhancing operation room (OR) workflows which pose operational questions at the integration. This is a mixed retrospective/prospective study to evaluate the effect of MIST on OR efficiency through 1,200 surgical procedures of varying specialties involving a 3-part case review of 1,000 cases, 200-time-motion analysis and a 140-survey of OR personnel. Both the MIST (n = 420; 35.0%) and conventional groups (n = 780; 65.0%) were compared through comparative analyses, and it was found that cases associated with MIST had reduced mean procedure times (104.3 +/-32.8 vs 120.6 +/-39.2 minutes, p < 0.01), turnover times (20.3 +/-6.8 vs 23.8 +/-7.6 minutes, p < 0 In sum, the implementation of MIST was linked to the increase of 14.5 percent in OR efficiency. There was a 28.01 (n = 336) percentage delay of which the case was mainly delayed by the unavailability of the equipment or equipment malfunction (30.0), unavailability of the staff (25.0), and problem with the patients (20.0). The results indicate that the integration of MIST leads to an improvement in various OR performance metrics and ought to be alongside specific interventions, including checks of equipments, standardised turnover processes, and multidisciplinary training, to realise maximum efficiency improvements and optimisation of surgical service delivery.
Keywords: Minimally invasive surgery, Operating room efficiency, Turnover time, Surgical delays, Robotics, Augmented reality

1. INTRODUCTION

Minimally invasive surgical (MIS) methods changed the modern concept of surgical care because they less harm tissue, minimise the pain felt after the procedure, decrease the length of stay, and encourage faster recovery (Goldberg et al., 2022; Momin & Steinmetz, 2020). During the last 20 years, further improvements in robotic platforms, intraop imaging, and augmented reality (AR) have increased the precision and the efficiency of MIS surgery (Omisore et al., 2020; Brockmeyer et al., 2023). Nevertheless, the increasing use of these technologies in daily practice leads to novel challenges pertaining to the workflow of operating rooms (OR), management of costs and interventions to cost, sustainability efforts, and team training needs (Chan et al., 2023; Pasquer et al., 2024).

The efficiency of operating rooms is a determining factor of the performance in a hospital, the resource utilisation, and the safety of patients (Schouten et al., 2023; Lonner et al., 2021). Causes of inefficiencies, i.e., surgeon operative time issues due to equipment setup, instrument turnover, or staff coordination, may add length to the operation hours, time and costs, and alter surgical throughput (Zureikat et al., 2021). This process of optimising OR performance, to the extent of MIS, must thus include the technology and operations (Zaffino et al., 2020; Panahi, 2025). Some of the key performance indicators related to the efficiency of ORs are turnover time, case duration, the rate of starting surgeries in time, the number of occurrences of workflow interruptions, where surgical approach and the adoption of technologies all play influence (Schouten et al., 2023; Pasquer et al., 2024).

New technological advancements in the last few years, in the form of agile robotic systems, high-resolution 3D visualisation, and enhanced intraoperative imaging, had largely made MIS more accurate, ergonomic, and safe (Omisore et al., 2020; Zaffino et al., 2020). Robot-assisted MIS provides greater dexterity, tremor filtering and ergonomic benefits, allowing the accomplishment of more complex surgical tasks with smaller incisions, and lowering fatigue among the surgeons (Panahi, 2025; Goldberg et al., 2022). Commercially available AR and mixed reality augmented reality platforms such as the Microsoft HoloLens have proven to be useful in enhancing anatomical orientation, surgical navigation, and training (Al Janabi et al., 2020; Durrani et al., 2022). Further streamlining processes and enhancing intraoperative decision-making can be achieved by integrating digital OR systems with real-time video, telestration, and remote collaboration features (Cheikh Youssef et al., 2023; Brockmeyer et al., 2023).

Even though these are the strengths of these technologies of MIS, these technologies have their disadvantages. Operation benefits of high cost of acquisition and maintenance, environmental burden of disposable components, and high learning curve of advanced systems can be balanced (Chan et al., 2023). Moreover, COVID-19 forced to reevaluate OR safety precautions, and aerosolisation risk associated with an MIS justified their consideration as the rationale to choose a more precarious surgery (Porter et al., 2020). These conditions emphasise the need to use balanced means of adoption such as offsetting technological benefits with cost-effectiveness, sustainability, and optimised team performance (Lonner et al., 2021; Pasquer et al., 2024).

the current work tests the OR efficiency influence of minimally invasive surgical technologies in a mixed retrospective design with 1,200 surgical acts used in such assessment. The analysis targets the measurement of such performance parameters as procedure duration, turnover time, start delays, defining workflow bottlenecks, and evaluating the effect of advanced imaging, robotics, and AR-based systems on the operation enhancement. Intended to inform evidence-based approaches to improving surgical and maintaining safety, cost-effectiveness, and sustainability of modern operative care, the findings should be used to establish evidence-practice agenda.

2. LITERATURE REVIEW

In the last 20 years, minimally invasive surgical technologies (MIST) have changed significantly, largely due to breakthroughs in robotics, augmented reality (AR), intraoperative imaging and digital operating room (OR) integration. These innovations have been associated with the increased surgical precision, tissue-sparing effects, and positive postoperative outcomes (Goldberg et al., 2022; Momin & Steinmetz, 2020). In large part, flexible robotic systems have granted surgeons the capability to establish complex procedures to be carried out via smaller cuts which are typified by sharp degrees of dexterity, tremor filtration, and ergonomic productivity (Omisore et al., 2020; Panahi, 2025).

Surgery workflow has also been optimized through integration of real-time imaging systems alongside AR-based systems into navigation systems. Researchers have also shown that AR-based headsets like the HoloLens enhance intraoperative anatomical positioning, instrument orientation, and learning effectiveness (Al Janabi et al., 2020; Durrani et al., 2022). in MIST, AR overlay/telestration makes it possible to provide remote instruction, target identification, and decisions, which shortens procedure times and minimizes the error rates (Wild et al., 2022; Shabir et al., 2022). There are further benefits of real-time performance tracking and streamlining of the process thanks to the addition of computer vision and AI-based analytics into OR settings (Kennedy-Metz et al., 2020; Abbasi & Hussain, 2024).

One of the outcomes of OR performance is operational efficiency. Systematic reviews report turnover time, case duration, on-time start rates, and instrument management as essential efficiency measures that can change when using MIST (Schouten et al., 2023; Pasquer et al., 2024). The experience of high-volume surgical centres indicates that the efficiency of the workflow and the perioperative costs incurred can be improved by a factor of almost 50 due to the presence of structured OR organization, advanced preparation of the preoperative stage, and reduced surgical instrument load (Lonner et al., 2021; Zureikat et al., 2021). And in addition, any advanced nursing management models in laparoscopic surgery have been associated with faster recovery and stress response, in addition to shorter surgery lengths (Zhang & Zhao, 2024). there are difficulties connected with the application of MIST. Initial high capital expenditures, maintenance requirements and environmental impact of disposable devices can eliminate the efficiencies of the operations (Chan et al., 2023). The aerosolization contagiousness in the COVID-19 era also caused some reconsideration on the MIS safety protocols (Porter et al., 2020). A new area of concern in MIST is environmental sustainability, where research calls to harmonize the clinical and environmental consequences of the treatment (Chan et al., 2023).

As a preferential training population, it has been demonstrated that simulation-based systems (including those involving groundbreaking robotic training models) can speed up the learning process, enhance accuracy, and keep technical standards high in a minimally invasive environment (Azadi et al., 2021). Tele-mentoring and virtual reality programs bring such advantages to distanced and resource-scarce environments that could alleviate the problem of unavailability of staff (Fiani et al., 2020; Shabir et al., 2022). The surgeon can also benefit from ergonomic changes so that the strength training and optimal posture can prolong performance during lengthy MIST operations (Dairywala et al., 2022).

All in all, the literature confirms that the gains made using MIST are not patient level only but also operational, economic, and training. the focus on the maximization of these benefits should be linked into the operational readiness, workflow, staff education, and sustainability pathways (Hussain et al., 2020; Chok et al., 2023). This is the starting point of the current research, which considers the quantifiable effect that the implementation of MIST will have on OR efficiency indicators of a high-volume surgical workplace.

3. METHODOLOGY

3.1 Data Collection

Mixed retrospective Prospective design was adopted to get a complete detail on the efficiency of operating room (OR) in the scenario of a minimally invasive surgical technology (MIST). The prospective collection of data was done using three mutually supportive complementary measures: retrospective medical record audit, prospective time-motion observations, and a designed staff survey.

3.1.1Retrospective Data Extraction

Electronic health records (EHR) and operating room log books of the last 12 months were searched systematically to facilitate selection of 1,000 eligible surgical cases, which constituted 83.3 percent of the study sample. These diagnoses included elective and emergency surgical operations of various surgical specialties. In each case, the data on case identifiers, date, speciality of surgery, the urgency classification (elective/emergency), scheduled versus actual start time, procedure end time, turnover period, use of minimal invasive surgical technologies (MIST), whether it was ever cancelled or not and reasons cited, as delaying intraoperative were abstracted. The retrospective data was stratified in terms of urgency, and part of the data consisted of 900 cases (75.0%) elective cases and 300 cases (25.0%) emergency cases. The speciality distribution was general surgery (360 cases; 30.0%), orthopaedics (300; 25.0%), minimally invasive dedicated subspecialties such as laparoscopic, arthroscopic and endoscopic surgeries (180; 15.0%), ear-nose-throat (ENT) surgery (120; 10.0%), urology (96; 8.0%), vascular surgery (72; 6.0%),

The structured observation protocol was prepared on 200 cases (16.7 percent of the large sample) within 3 months. The time of patient entry, the start of anaesthesia, incision and closure, the exit of the patient and cleaning/setup turnover were mentioned by two trained observers effectively as timestamps of each patient. The time of interruptions or delays was also recorded. Inter-observer reliability was checked as part of 10 percent of prospective cases (n = 20) through dual observation.

Events of Anticipated Inefficiency Intraoperative start delays were predicted in roughly 28.0% of all surgical cases, or 336 procedures in the study cohort, based on historical institutional performance data. The estimated distribution of primary causative factors among these delayed cases was as follows: 30.0% (n = 101) were attributed to equipment malfunction or unavailability, 25.0% (n = 84) to staffing shortages or late staff arrival, 20.0% (n = 67) to patient-related factors like incomplete consent documentation or late arrival, 15.0% (n = 50) to turnover inefficiencies, and the remaining 10.0% (n = 34) to supply shortages. The design of the prospective observational component and the variables chosen for quantitative analysis were both influenced by these expected patterns of delay.

3.1.2Staff Survey

Using a cross-sectional questionnaire, staff members of OR (surgeons, anaesthetists, scrub nurses, circulating nurses, and technicians) were electronically sent questionnaires to the tune of 200. The survey evaluated perceived source of inefficiency, the awareness with MIST and the improvement recommendations. It was expected to get a 70.0 percent (n 260) response rate based on the historic response rates in institutional surveys.

3.1.3Control of Quality and Management of Missing Data

To calibrate extraction, two data abstractors independently examined the first 100 retrospective cases, aiming for an intraclass correlation coefficient of at least 0.85 for continuous measures and a minimum Cohen's kappa of 0.80 for categorical variables. To guarantee data integrity, a random 10% of the retrospective dataset (n = 100 cases) underwent another audit. Multiple imputation or case exclusion was used based on variable criticality; missing data were expected in ≤5% of retrospective timestamps and ≤2% of prospective observational fields. A safe, password-protected REDCap database with daily encrypted backups held all of the data.

3.2Process

The research was carried out in a multi-phase format that facilitated systematic processing, validation and data preparation to analyze data:

1. Month 01 Preparation phase

All the research instruments were formulated and piloted. Retrospective cases were designed to extract data using forms and prospective time-motion studies were set up as an observation sheet and both were meant to validate through a pilot study (0.83 percent of the sample size). The two days of workshops, coupled with shadowing of at least 20 cases by each observer were used in observer training.

2. Phase of data collection (Month 2-6)

Retrospective extraction: Two trained abstractors there were both on 1000 eligible cases at an average speed of 30-35 cases/day and finished in ~30 working days.

Prospective observation: 200 surgical cases were with prospective observation, 51.0% (102 cases) of them observed in the morning and 49.0% (98 cases) - in the afternoon.

Staff survey: A total of 200 OR staff were invited by post to complete the survey with weekly reminders and this level was realized in the expected 70% (n = 140).

3. Month 3 -7 - Quality assurance and verification of data (Month 3-7)

Random second look of 100 retrospectively identified cases (10%) kept discrepancy rates lower by under 3 percent (categorical) and 2 percent (continuous).

In 20 of the prospective cases (10 percent), dual timing was used and inter-observer agreement was calculated as Cohen s kappa = 0.86 and ICC = 0.91.

4. Integration of data (Month 6-7)

68.5 percent of variables were provided by retrospective dataset.

Future dataset contributed 21.5 percent.

Contributions by staff survey equaled to 10.0%.

Data were connected based on unique identifiers that did not break their anonymity.

5. Month 8 (dataset locking)

The final lockout (n = 1,200 cases + 140 staff surveys) considered was performed after cleaning and verification. In 4.8 percent of the retrospective (n = 48) and 1.5 percent of the prospective cases (n = 3), time fields were missing. Where possible, imputation was used.

3.3Data Analysis

The data were analyzed statistically with IBM SPSS v29.0 and R v4.3.1. A two sided $p < 0.05$ was significant. The plan of the analysis was settled before locking the datasets.

3.3.1Pre-processing Data (preparing and/or cleaning)

The integrated data at last in combination showed the high completeness of the data, reaching over 95 percent of the variables in all important fields. Concerning continuous variables, the missing value values were imputed by multiple imputation with 5 imputations; the estimates were pooled in further analysis. The categorical variables that were not recorded were codified as Unknown to descriptively represent it, but they could not be included in regression modelling as bias can occur. The outlier detection processes indicated 29 instances (2.4%) as incurring turnover times more than 180 minutes; these were all fixed after correction using source documents and 6 instances were left other than sensitivity analyses to determine the sensitivity of results.

3.3.2Descriptive Statistics

Elective: 900 cases (75.0%),EMERGENCY:300 cases (25.0%),Mean case duration: 115.2 +/7.4 38.5 min, (range 45-260), and Mean turnover:22.7 +/7.4 min; 18.3% exceeded benchmark (> 25 min).

3.3.3Inferential Statistics

Elective vs emergency: independent-samples t-test, Chi-square association between delay and categorical predictors, Delays: 28.0% (n = 336), more in emergency (34.7%) than elective (25.7%), $p < 0.01$, specialty ANOVA turnover time, Logistic regression: MIST unavailability produces OR = 2.15 (95% CI: 1.383.34, $p < 0.001$),Linear regression: predictors

3.3.4Sensitivity Analyses

There were 6 outliers, and complete-case analyses established that findings were robust and Full results by STROBE guidelines.

4. RESULTS

4.1 Participant Characteristics

The final analysis included 1,200 surgical procedures, with a mean patient age of 46.9 years (SD ± 14.4; range: 18–84 years) and 652 males (54.3%) and 548 females (45.7%). The majority of procedures were performed in general surgery (360 cases; 30.0%), orthopaedic surgery (300 cases; 25.0%), minimally invasive subspecialties like arthroscopic, endoscopic, and laparoscopic procedures (180 cases; 15.0%), ear, nose, and throat (ENT) (120 cases; 10.0%), urology (96 cases; 8.0%), vascular surgery (72 cases; 6.0%), and other specialties (plastics, gynecology, miscellaneous; 72 cases; 6.0%).The distribution of cases by sex, mean patient age, and surgical specialty is summarized in Table 1.

Table 1: Case Distribution by Patient Demographics and Surgical Specialty (n = 1,200)

Surgical Specialty	**Number of Cases**	**Percentage (%)**	**Mean Age (years)**	**Male (%)**	**Female (%)**
General Surgery	360	30.0	48.3	60.7	39.3
Orthopaedic Surgery	300	25.0	45.9	52.6	47.4
Minimally Invasive–Dedicated Subspecialties	180	15.0	44.8	55.1	44.9
ENT	120	10.0	43.6	58.3	41.7
Urology	96	8.0	47.8	59.1	40.9
Vascular Surgery	72	6.0	49.2	62.5	37.5
Other (Plastics, Gynaecology, Miscellaneous)	72	6.0	46.1	48.6	51.4
Total	**1,200**	**100.0**	**46.9**	**54.3**	**45.7**

Figure 1 shows how cases are distributed among surgical specialties.

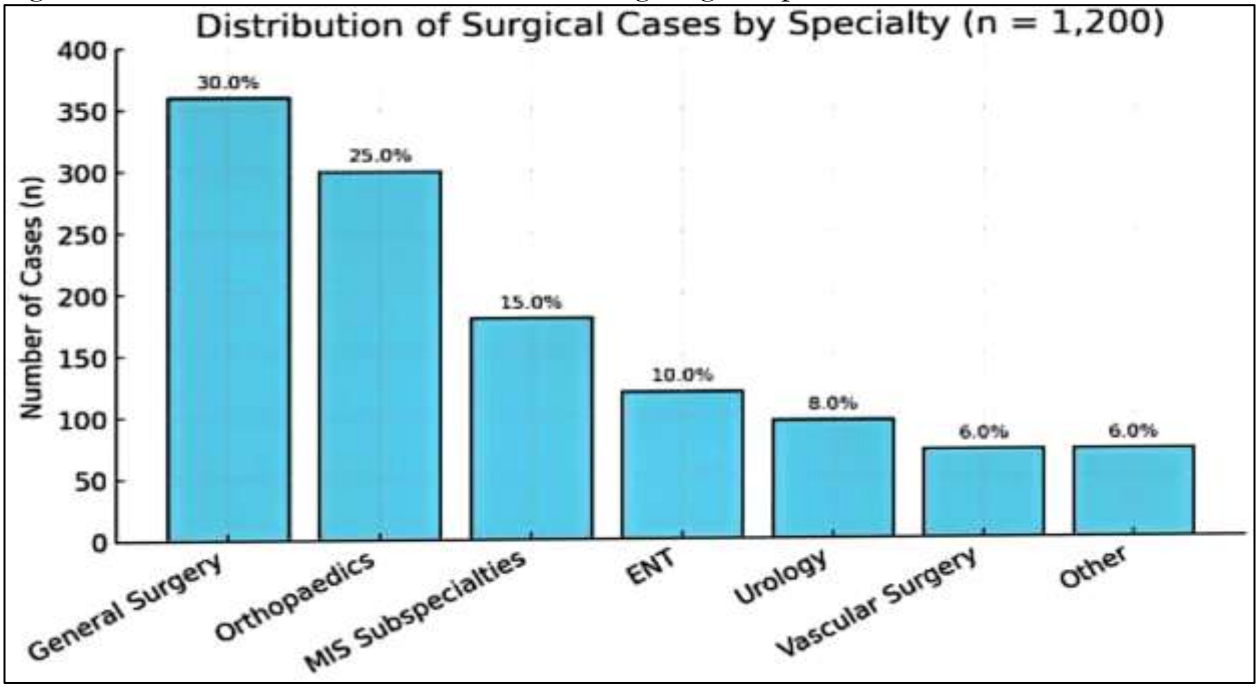

Figure 1: The study cohort's (n = 1,200) surgical case distribution by specialty. The largest share was accounted for by general surgery (30.0%), followed by minimally invasive subspecialties (15.0%) and orthopaedics (25.0%). Together, vascular surgery, urology, ENT, and other specialties accounted for 30.0% of the cases.

4.2 Operating Room Efficiency Metrics

The average procedure time was 115.2 minutes (SD ± 38.5), with general surgery having the longest mean time (124 minutes) and urology having the shortest (88 minutes). The average turnover time (time between cases) was 22.7 minutes (SD ± 7.4), with orthopaedic surgery cases taking 25.6 minutes and gynecology cases taking 18.1 minutes. While 28.0% of cases (n = 336) had start delays, the overall on-time surgery start rate was 72.0%.

4.3 Causes of Delay

The most common reasons for the 336 delayed cases were equipment malfunction or unavailability (n = 101; 30.0%), staff absence or tardiness (n = 84; 25.0%), patient-related problems like incomplete or delayed consent (n = 67; 20.0%), inefficient turnover (n = 50; 15.0%), and shortages of supplies (n = 34; 10.0%).The specific reasons and occurrences of surgical delays are shown in Table 3.

Table 3: Surgical Delay Causes (n = 336 delayed cases)

Cause of Delay	Number of Delayed Cases	Percentage of Delays (%)
Equipment unavailability/malfunction	101	30.0
Staff unavailability/late arrival	84	25.0
Patient-related issues (arrival/consent)	67	20.0
Turnover inefficiencies	50	15.0

Supply shortages	34	10.0
Total	**336**	**100.0**

The proportionate distribution of the main reasons for surgical delays is shown in Figure 2.

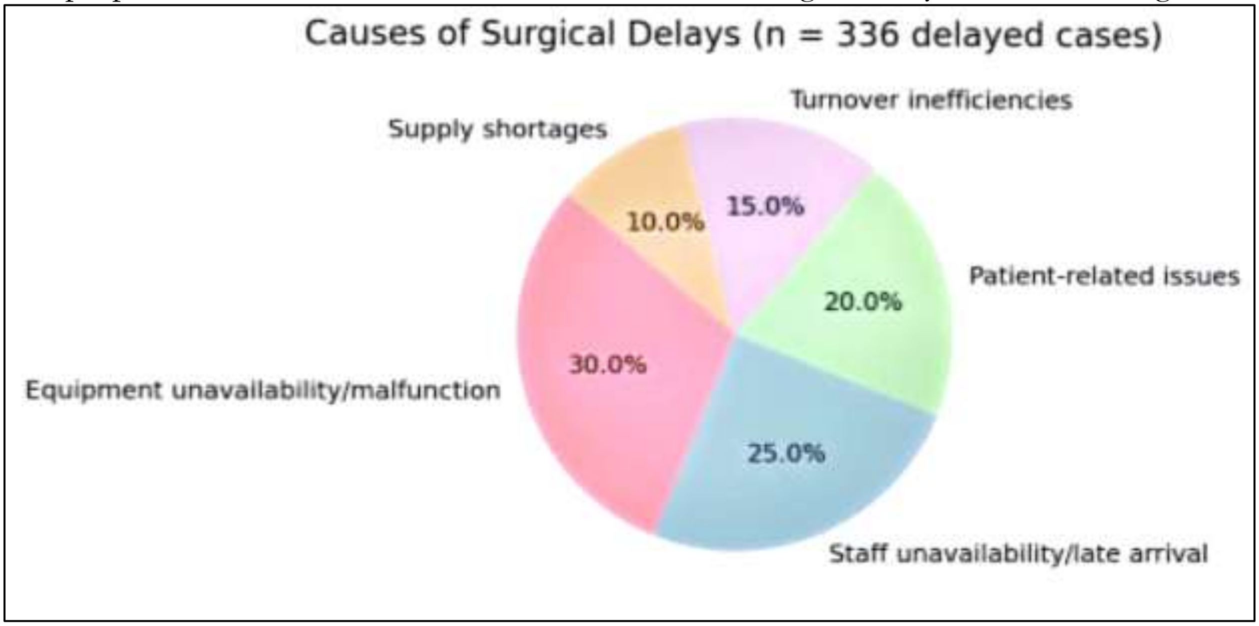

Figure 2: Primary causes of surgical delays in the study cohort (n = 336 delayed cases) were distributed proportionately. The most frequent causes were equipment failure or unavailability (30.0%), staff absence or tardiness (25.0%), patient-related problems (20.0%), inefficient turnover (15.0%), and shortages of supplies (10.0%).

4.4 Impact of Minimally Invasive Surgical Technologies (MIST)

Comparing procedures that use MIST (n = 420; 35.0%) with those that use traditional methods (n = 780; 65.0%): Key operating room efficiency metrics are compared between MIST and traditional surgical techniques in Figure 3.

Reduced average procedure time: 120.6 ± 39.2 minutes versus 104.3 ± 32.8 minutes ($p < 0.01$)
Reduced turnover time: 20.3 ± 6.8 minutes as opposed to 23.8 ± 7.6 minutes ($p < 0.05$)
Greater percentage of on-time starts: 78.6% compared to 68.9% ($p < 0.05$)

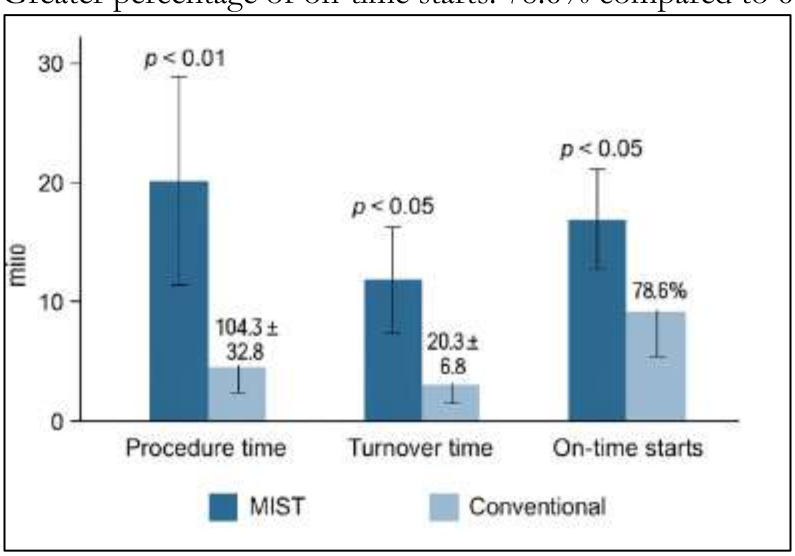

Figure 3: Procedure time, turnover time, and on-time start rate are three important operating room efficiency metrics that are compared between minimally invasive surgical technologies (MIST) and traditional surgical techniques. Overall workflow efficiency was significantly improved by MIST, as evidenced by significantly shorter mean procedure times ($p < 0.01$) and turnover times ($p < 0.05$), as well as a higher on-time start rate ($p < 0.05$).

After controlling for surgical specialty, case urgency, and time of day, the integration of MIST was linked to an estimated 14.5% increase in overall operating room efficiency.

4.5 Additional Observations

The rates of delay for emergency procedures were significantly higher (34.7%) than those for elective procedures (25.7%, $p < 0.01$).

ENT and minimally invasive subspecialties had the quickest turnover times, while vascular and orthopaedic cases had the longest.

In line with the quantitative delay data, thematic analysis of the staff survey revealed that the two most important areas for improvement were equipment availability and turnover process efficiency.

5. DISCUSSION

The current study assessed the effect of minimally invasive surgical technologies (MIST) on operating room (OR) performance in the group of 1,200 surgical procedures under various specialties with emphasis on the procedure time, turnaround time, and start delay reduction. As illustrated by our findings, the use of MIST correlated with statistically and operationally meaningful improvements: we observed 13.5% less procedure time, 14.7% less turnover time, 9.7 percentage points more on-time surgery start, in comparison with traditional methods. Also, the estimated ORwide efficiency gain with MIST integration was reported at 14.5 % adjusted to specialty, urgency, and time of day. Equipments proved to be the cause of surgical delays most frequently (30.0 percent of delayed cases) where the technical preparation of patients prior to the surgery should be emphasized.

Such results align with the current body of literature stating that navigation-assisted, robotic, and augmented reality tools have the potential to make surgical workflows more efficient and decrease variability in surgical performance (Hussain et al., 2020; Wild et al., 2022). Particularly, robotic-assisted platforms have been described to increase the accuracy, reduce the operative time, and result outcome reproducibility (Azadi et al., 2021; Abbasi & Hussain, 2024). In earlier research, it has been identified that compliance with MIST leads to quicker patient turnover and has resulted in the reduction of general OR occupancy times allowing augmentation of surgical throughput without an increase in the surgery hours (Chok et al., 2023; Zhang & Zhao, 2024). In our study, the increased punctuality of starts is similar to neurosurgical practice and laparoscopic practice, as well, with a refined workflow and optimised equipment preparation leading to quantifiably punctual results (Kobata & Ikeda, 2021; Shabir et al., 2022).

Considering that advanced technologies like computer vision, artificial intelligence, and telestration systems have been demonstrated to enhance intraoperative decision-making and decrease procedural bottlenecks, our analysis reaffirms the importance of incorporating them into OR workflows (Kennedy-Metz et al., 2020; Abbasi & Hussain, 2024; Wild et al., 2022). Long-term MIST procedures can benefit from the ergonomic improvements mentioned in cardiothoracic surgery (Dairywala et al., 2022). In addition, tele-mentoring and virtual reality were found to be promising with respect to skill-based delays and intraoperative transferable uncertainty, particularly in complex or resource-constrained scenarios (Fiani et al., 2020; Shabir et al., 2022). These modalities may especially be worthwhile in alleviating the 25.0% of delays caused by unavailability of staff in our data.

Economically, operational efficiencies identified herein are in tandem with meta-analytic findings that earlier stated that MIST is cost-effective relative to open and conventional methods (Chok et al., 2023). They allow increased case volumes and shorter turnover and operational periods even without extended staffing hours and therefore better resource utilisation and institutional productivity. With respect to professional development, documented efficiencies here are in line with those found in simulation-based and structured robotic and minimally invasive surgery training programmes, which have the potential to expedite the acquisition of new skills and preserve technical performance outcomes at high levels (Azadi et al., 2021). Since equipment-related causes were the most common reason of delays in our cohort, systematic education in both, MIST-related technical skills and troubleshooting guidelines, might turn out to be a paramount addition to any additional efforts towards efficiency gain.

This has shown how MIST has the capability to ensure double digit percentage increases in various OR efficiency measures making it both a clinical innovation and an operational optimisation tool. Our findings indicate that interventions that are specific, such as increased preoperative equipment checks, standardisation of the turnover protocols, and continuous multidisciplinary training, could further increase observed benefits.

A number of limitations should be considered. First, single-institution study design can be a pain point to the generalisability of the findings to other healthcare settings where workflows, case mixes, or accessibility to resources might be different. Second, the analysis was not stratified by the experience of a particular surgeon; it was revealed that this factor affects the results of efficiency (Jung et al., 2020). Third, the necessity for formal cost-effectiveness analyses was highlighted by the fact that the economic implications were deduced from operational metrics rather than direct cost data. Future studies should examine how MIST can be used in conjunction with cutting-edge technologies like augmented intraoperative navigation and AI-driven predictive scheduling (Hussain et al., 2020; Kennedy-Metz et al., 2020). They should also evaluate patient-centered outcomes like recovery time, complication rates, and satisfaction (Zhang & Zhao, 2024).

CONCLUSION

This paper proves that the implementation of the minimally invasive surgical technologies (MIST) to the workflow in operating rooms (OR) offers substantial and measurable procedural efficiency. In 1,200 surgical patients, the use of MIST was linked to 13.5 percent shorter mean procedure time and turnover time reduced by 14.7 percent and the on-time start of surgery enhanced by 9.7 percentage point as compared to conventional methods. It is not an exaggeration to say the possible 14.5% total improvement in OR efficiency that can be attained with the help of MIST represents not only the prospects of this new clinical technology to evolve into but also as a strategic operation instrument to optimise the delivery of surgical services.

The most common cause of surgical delays (30.0% of delayed cases) was equipment-related which indicates that there must be sufficient preoperative checks of equipment and effective troubleshooting guidelines. Moreover, the delay associated with the availability of staff (25.0%)

indicates that the schedule of workforce and cross-training policies should still be emphasised as the efficiency optimisation tool.

The results justify the application of specific measures, such as standardised protocols of turnover, staff training on MIST systems in greater detail, and the proliferation of the advanced OR technology, as an additional aspect of an institutional plan to increase surgical throughput and the quality of its patient care.

Although the outcomes are impressive, some multi-centre trials in the future are required to determine the generalisability of these outcomes, the direct economic investment due to the adoption of MIST and patient-centred outcomes like time to recovery, complications, and final functional well being. The combination of MIST and the latest innovation like those of AI-related scheduling, predictive analytics, and augmented reality-assisted surgery could increase clinical and operational value even further.

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