The Impact of Proper Surgery Planning on Operating Room Efficiency. An Italian Case Study in 2021

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Abstract The study aims to investigate whether correct organizational procedures associated with correct operating room planning and scheduling led to fewer canceled patients and improved OR performance indicators. The following performance and efficiency metrics were monitored: Start Time Tardiness, Turnover Time, Overtime, Under Utilization, and Case Cancellation Rate. We conducted a retrospective case

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study at the Orthopedic Institute Rizzoli of Bologna, a specialized orthopedic surgery hospital. The analysis considered 674 operations performed between October and November 2021, including cases from all operating units. In order to evaluate the correct planning of operations, we divided the slots retrospectively based on correct scheduling: those with more than 50% of correctly scheduled surgeries and those that fell short of this percentage. The results of performed t-tests indicated a statistically significant difference for Turnover Time and Start Time Tardiness. For the group of operations that followed the complete organizational scheduling procedure, the t-tests showed an average reduction of 8.35 min (−19.5%, $p < 0.05$) for Turnover Time per single operation and 13.12 min (−17.8%, $p < 0.01$) shorter Start Time Tardiness. No significant differences were observed for Under Utilization, Overtime, and Case Cancelation Rate. In conclusion, we found completeness in surgical scheduling had a positive effect on operating room waste time, with reductions of over 17% in Turnover Time and Start Time Tardiness. These results highlight the importance of proper surgical programming for hospital managers and the areas with more room for improvement.

Keywords Operating room efficiency · Surgery planning

JEL Classification Codes I18 · I20 · M10

1 Introduction

Growing demand for surgical services, correlated with the phenomenon of an aging population (Etzioni et al. 2003) and the rise of capital-intensive technological innovations requires substantial cost-saving measures inside hospitals (Schwierz 2016; Italian Guidelines for the Governance of the Planned Surgical Patient Pathway 2020). The Covid-19 Pandemic placed further stress on Health Systems due to disruptions to routine hospital services, further highlighting the urgent need for good practices in order to boost efficiency and productivity (CovidSurg Collaborative 2020). Within this framework, Operating rooms (ORs) represent both the core unit of hospital surgical production and the most critical cost centers of Healthcare Systems, accounting for 35 to 40% of total costs and generating 60–70% of revenues (Healey et al. 2015).

Thus, ORs require stringent monitoring, as their efficiency has important implications for cost savings, patient satisfaction, and medical team morale (Rothstein and Raval 2018). In particular, surgery planning and scheduling have the potential to improve efficiency, while inefficient scheduling has a detrimental effect on healthcare providers, resulting in the suboptimal use of resources, lower returns on investment and longer waiting lists for patients (Erdogan and Denton 2011). In context, "optimal efficiency is achieved by the ability to deliver the highest-quality care with the minimal use of time, money, and space" (Healey et al. 2015, p. 1). Therefore "improving efficiency means shorter case durations, rational scheduling of various types of surgery, and minimizing nonoperative time" (Marjamaa et al. 2008, p. 596). Focus on Healthcare System productivity and output is crucial in times of budget constraints.

The theoretical framework is rooted in the teachings of Operation Room Management, which aims to provide appropriate tools for monitoring and optimizing processes (Marjamaa et al. 2008). This discipline, combined with the surgical pathway guidelines in place in Italy (Guidelines for the Governance of the Planned Surgical Patient Pathway 2020), defines systematic controls on the performance levels of different surgical phases through various indicators and rules for proper surgical planning. The OR optimization process consists of three phases: preoperative, operative, and postoperative (Rothstein and Raval 2018). OR planning can be divided into three different decision levels (Zhu et al. 2019). The strategic level consists of capacity planning, capacity allocation, and case mix choices, spanning several months to 1 year or longer. Secondly, the tactical level allocates OR time to surgical specialties according to specific requirements, and determines workload distribution. Finally, the Operational level involves short-term decision-making, matching, and the scheduling of resources and patients. This analysis will focus on the Operational level, examining the use of proper scheduling by evaluating its potential effects on productivity and reporting on two scheduling tools currently in use at the Rizzoli Institute, with five performance indicators commonly applied in Operating Room Management.

A considerable volume of literature has been published on operating room planning and surgical case scheduling. Like most previous papers, our work focused on elective patients (Cardoen et al. 2010). Elective surgery scheduling involves assigning an operation date, a starting time, and an OR for elective surgeries selected from the hospital waiting list (Marques et al. 2015). It is impossible to plan for emergency patients since they require urgent treatment, which is why they are less commonly involved in research studies on this topic. Current OR theory indicates that the problem of optimization arises due to the number of participants involved (OR managers, surgeons, OR staff, patients) and the level of uncertainty (duration uncertainty, arrival uncertainty, resource uncertainty, and care requirement uncertainty). Mathematical models such as the bin-packing model, flow-shop model, and stochastic and multi-criteria models have been formalized to solve surgery planning problems, yet "despite the great deal of theoretical work that has been published, none seems to have a profound effect on the real-world practice of OR management" (Zhu et al. 2019, p. 794). Therefore, this concept appears to have been inadequately considered by earlier research but is relevant in practice, despite not always being ensured. Zhu et al. (2019, p. 758) clearly stated in their literature review that "the performance of operating theatres is largely influenced by the planning and scheduling policies used in practice"; however, existing scientific literature focuses on the optimization of surgery sequencing and lacks a tangible demonstration of the connection between proper scheduling and OR performance. Despite different approaches to maximizing OR efficiency, no evidence in literature indicates the importance of correct, complete, and accurate performance of all organizational procedures associated with operating room planning and scheduling by all operators involved. Routine is fundamental in

OR planning (and hence OR efficiency), but within the hectic reality of hospitals, its implementation by operators is not always possible. Single operators do not always have a “whole hospital system” perspective and sometimes organizational procedures linked to OR planning and scheduling are considered trivial administrative tasks. However, the accurate execution of these procedures by all staff members involved is crucial for OR planning, scheduling, and overall OR management. All individual patient processes require planning to ensure: the availability of the right person at the right time on the ward, transportation to surgical facilities, preparation of correct surgical instruments in the correct OR, and so on. Inadequate planning and scheduling of this process results in a drastic decrease in efficiency. With this study, we want to fill the existing literature gap by assessing whether proper surgery scheduling is associated with better OR performance indicators, by measuring the differences between correctly and incorrectly scheduled slots at a surgical hospital. The conclusions would provide hospital managers with invaluable insight on the importance of procedures associated with correct operating room planning and scheduling by all staff members involved. Correct scheduling is a fundamental prerequisite for the implementation of other improvement strategies.

2 Methods

This is a cross-sectional retrospective case study structured according to Yin’s (2013) theoretical considerations on case study design. The single-case study rationale is to critically support the general theory about correct operating room scheduling and OR performance. Data were retrospectively collected from the IRCCS Rizzoli Orthopedic Institute (IOR), a highly specialized public hospital and research center in orthopedics and traumatology. The IOR is part of the Emilia Romagna Regional Health Service. It performs tasks of high clinical-organizational expertise, pursues research and training of internationally recognized prestige, and made the 2022 Newsweek Magazine ranking of the top five Orthopedic Institutes in the world. This Hospital was chosen due to the quality and availability of data, and due to its rigorous adherence to national and regional Resolutions. No. 272 of 03/13/2017, Emilia Romagna is a landmark regulation that paved the way for further national legislation on waiting list governance, and the standardization of pre-operative and perioperative management pathways for hospital productivity enhancement. The legal framework stipulates close monitoring of average room utilization times per surgery, further incentivizing the full utilization of operating rooms with the formulation of weekly schedules based on objective and significant data.

Moreover, thanks to its multidisciplinary expert team, IOR has played a key role in drafting and implementing national good practice guidelines in the past year. The IOR has twelve distinct and highly specialized Operating Units. In particular, the medical areas of intervention are orthopedic oncology, spinal surgery, pediatric orthopedics, prostheses revision and replacement, surgical therapy of severe infectious bone disease, foot surgery, and upper limb surgery. The institute has a horseshoe-shaped operating block of 10 operating rooms in which medium-to-high complexity orthopedic surgeries take place. Regular operating room days are scheduled from Monday to Friday and are divided into two slots. Each slot lasts 380 min: the morning session takes place from 7 a.m. to 1:20 p.m., while the afternoon session starts at 1:20 p.m. and finishes at 7:40 p.m. As stated in the introduction, we focused our research on elective surgery only, since the IOR does not accept urgent cases, indeed emergencies are treated in other hospitals in the Bologna Metropolitan Area. The description of operative phases (pre, peri, post) in National Guidelines includes a specific section for surgery scheduling, stressing the importance of planning and the rules for the proper preparation of production factors (room space, clinical and technical specialists, materials, and instruments). It establishes two distinct levels of planning: the Weekly Operating Note (WON) and Daily Operating Note (DON). The WON must be completed on the Thursday of the week before operations. The Programming Group checks it in terms of integrity and compliance with internal directions. Macro errors or inconsistencies are adjusted at the weekly meeting every Thursday at the Medical Direction Office. The weekly scheduling proposal is prepared for patients from the Waiting List identified as eligible for surgery at the pre-admission check. It should be prepared in compliance with assigned operating room utilization times, hospitalization, and bed availability. After validation, the proposed Operating Note becomes definitive and is the essential tool for the proper execution of the organizational path toward operating room activities.

The DON derives directly from the WON and must be prepared and sent no later than 12 p.m. on the day before operations. It must contain and confirm data from the corresponding WON. Any subsequent modification must be reported to the anesthesiology and nursing coordinators. For the purpose of our study, patients had to be present in both WON and DON within the terms in order to be considered correctly scheduled.

The WON is the first tool used for scheduling patients and must include the following elements:

- patient's personal data,
- surgery duration,
- type of surgery,
- laterality (if needed),
- allergies report,
- request for transfer to the Intensive Care Unit (ICU) or Recovery Room (RR),
- request for room electro-medical devices/equipment that differs from the standard setting (e.g., specific surgical bed, fluoroscope),
- indication of the instrumentation and implantable material to be used; must contain all necessary elements for correct and complete identification of material to be prepared and taken into the OR,
- first operator,
- type of anesthesia,
- patient position,
- prediction of airway risk,

- possible infection/colonization of multi-resistant micro-organisms.

In addition to the list above, the DON also requires a more specific indication of instrumentation for surgery. Correct identification of material that must be prepared and taken into the operating room is crucial.

The IOR internal procedures provide the following practices for the slot's scheduling:

- Patients who have already been postponed should generally be scheduled at the beginning of the session to avoid further suspensions;
- the most demanding cases in terms of total planned time (preparation, surgical time, and operating room exit) should usually be made at the beginning of the session;
- unpostponable cases cannot be placed at the slot's end;
- cases with air-borne infections should be included at the end of the session;
- latex-allergic patients must be placed in the latex-free OR or at the beginning of the session in ordinary ORs;
- The first three patients on the operating note should maintain their list position to ensure the supply of the planned materials.

The Operations Group is responsible for enforcing the rules and implementing the necessary corrective actions when needed.

2.1 Study Design

The observation period started on the 26th of October 2021 and ended on the 26th of November 2021.

The following procedure was used for analysis:

1. Review of the 4 WONs and 31 DONs;
2. Analysis of performed surgeries and comparison with scheduled ones;
3. Computation of the percentage of scheduled operations in both WON and DON (correctly planned surgeries) for each daily slot;
4. Formation of two groups based on the percentage of correctly scheduled patients per slot. From the experience of the Institute's Programming Group, we used 50% as the cut-off value. Slots with more than half of operations that follow the entire planning process are thus placed in the "correctly scheduled ORs" group and all others in the "incorrectly scheduled ORs" group. Omitted patients or interventions present in only one of the two scheduling tools and submissions beyond the prescribed deadlines are considered incorrect for the purposes of this analysis.
5 Finally, we performed a T-test and Mann–Whitney test on both groups according to data distribution (McElduff et al. 2010). Tested performance indicators are:

Table 1 Performance indicators definitions

Performance Indicator	Formula	Definition	Meaning
Start time tardiness	STT = StartChirOp – StartSlot	Difference between the actual start of the first surgical operation of the day and the programmed time	Start delay of the first intervention
Turnover time	TT = InORp2 – OutORp1	Difference between the next patient's entrance into the OR and the exit of the previous patient	Timeframe for the preparation of the OR, the sum of cleaning, and the setup time
Overtime	OT = OutOR – EndSlot	Difference between the exit of the last patient from the OR and the programmed slot end time	Additional time used to finish the last patient's surgery
Under utilization	UU = EndSlot – OutOR	Difference between the programmed slot end and the actual last patient exit	Timeframe of not utilized Operating room due to an early exit of the last patient
Case cancellation rate	N. of cases canceled/ N. of total cases	The ratio of canceled patients and the total number of cases performed	It describes the rate of programmed patients who did not undergo surgery

Start Time Tardiness (STT), Turnover Time (TT), Overtime (OT), Under Utilization (UU), and Case Cancellation Rate (CCR), as defined by Macario (2006). Definitions are in Table 1.

Data was obtained from the institutional operating records platform. Some observations have been excluded from the analysis due to measurement errors, such as excessive or omitted timings. Private practice surgery, day Hospital, or outpatient surgeries were not included in the analysis.

3 Results

674 surgeries were performed in the observed period (Table 2).

– 42% (282) followed the complete scheduling process;
– 41% (280) were in one of the scheduling tools only;
– 17% (112) were not in the programming tools at all, or were scheduled beyond the deadline.

Table 2 Surgeries summary

Surgeries performed				
Total	Patients in both WON and DON	Patients only in DON	Patients only in WON	Patients not scheduled or scheduled beyond the deadline
674	282	274	6	112
100%	42%	41%	1%	17%

With the chosen breakdown (cut-off at 50%), the 172 slots have been split into two groups: 95 slots went into the "incorrectly scheduled" group and 77 "correctly scheduled" one.

A total of 47 postponed scheduled patients were recorded in the observed month.

Table 3 shows completion rates for fields in the WON. These data are part of the hospital's weekly note efficiency report, presented and discussed at the Planning Group every Thursday at 1 p.m. at the medical direction office with unit coordinators. The scores in the last column are low because this field is only filled in if OPT or Allen Bed are required.

The results of the *t*-test performed (Table 4) showed a statistically significant difference in Turnover Time and Start Time Tardiness. Indeed, for the "Correctly scheduled," group, the *t*-test showed an average reduction of 8.35 min (−19.5%, $p < 0.05$) for Turnover Time per single operation and a 13.12 min (−17.8%, $p < 0.01$) shorter Start Time Tardiness. We performed a Mann–Whitney test due to the asymmetric distribution of other variables. No statistical differences between both groups emerged from this non-parametric test (Table 5).

Our results are mostly aligned with the general assumption that more accurate planning leads to better OR performance. Results indicate a significant impact of correct scheduling on STT and TT, while UU, OT, and CCR do not significantly differ.

4 Discussion and Limitations

The Study indicates a clear improvement of TT and STT in the "correctly programmed" slot group. This may be due to the early morning calling of the first patient, more thorough case study, and surgery preparation with the availability of instrumentation, radiological equipment, and support staff. Reducing these times is crucial, as "prolonged operating room turnover time remains an area of frustration for surgeons, anesthesiologists, perioperative staff and administrators. Long operating room wait times also erode patient satisfaction" (Cerfolio et al. 2019, p. 1004). Moreover, saved time implies an increase in room efficiency, with an equal amount of resources involved. Childers and Maggard-Gibbons (2018) reported that on average,

Table 3 Weekly note completeness report, period of observation 26th October 2021–26th November 2021

Completion percentage for each field of the weekly operating notes												
Operation unit	Scheduled surgeries	Surgery duration (%)	Type of surgery (%)	Laterality (%)	First operator (%)	Position (%)	Materials (%)	ASA (%)	Intubation (%)	Recovery room (%)	Fluoroscope (%)	OPT or ALLEN bed (%)
Unit 1	22	100	100	100	0	0	95	55	55	14	73	14
Unit 2	69	100	100	100	99	100	61	41	38	12	46	0
Unit 3	57	100	100	100	98	100	98	89	94	68	35	0
Unit 4	16	100	100	88	0	6	88	56	44	31	19	0
Unit 5	19	100	100	100	0	89	47	37	44	0	47	0
Unit 6	119	100	100	100	99	3	68	7	37	0	56	0
Unit 7	11	100	100	91	36	100	91	27	7	0	100	100
Unit 8	9	100	100	100	89	89	89	44	27	11	100	100
Unit 9	12	100	100	100	100	75	58	33	33	25	33	0
Unit 10	3	100	100	100	100	100	0	0	0	0	0	0
Total/mean	**337**	**100**	**100**	**99**	**80**	**56**	**74**	**37**	**35**	**18**	**51**	**7**

Table 4 *t*-Test results

Characteristic	Not correctly scheduled ORs, N = 95[a]	Correctly scheduled ORs, N = 77[a]	*p*-Value[b]
Start time tardiness (minutes)	74.13 (24.30)	60.95 (25.53)	0.001
Mean turnover time (minutes)	44.09 (25.55)	35.50 (20.52)	0.019

[a]Mean (SD)
[b]Welch Two Sample *t*-test

Table 5 Mann–Whitney test results

Characteristic	Not correctly scheduled ORs, N = 95[a]	Correctly scheduled ORs, N = 77[a]	*p*-Value[b]
Under utilization (minutes)	11.01 (38.83)	7.66 (17.77)	0.8
Overtime (minutes)	25.59 (41.57)	25.31 (31.18)	0.6
Canceled case rate (per day and OR)	0.08 (0.21)	0.19 (0.29)	0.2

[a] Mean (SD)
[b] Wilcoxon rank sum test

1 min of a running OR costs 36 dollars, so 13 min less TT for every operation means thousands of dollars saved every day for the Hospital.

We compared our results to the standardized scoring system presented by Macario (2006). In his paper, Macario assigns points to ORs according to their performance, defined in eight metrics, differentiating between low, medium, and high performers. Our "correctly scheduled" group has a TT of 35.30 min, thus falling in the medium class (40 min < TT < 25 min), while the "not correctly programmed" group belongs to the worst class (TT > 40 min). Similarly, the value of STT (60.57 min) brings the first group near to the upper limit of the medium class (60 min < STT < 45 min). The high values for STT could be explained by the high complexity of operations performed at the IOR requiring long anaesthesiological induction times.

UU e OT are not statistically significant, nor is the Canceled Case Rate. Despite the high P value, this indicator appears to yield a counterintuitive result: the number of postponed patients is higher for the Correctly scheduled group. A reasonable explanation for this is that it is impossible to monitor and capture unscheduled cancelled patients. This problem should be taken into consideration in further analysis. The lack of completeness of the WON and the fact that only 42% of patients undergoing surgery followed the complete scheduling process can lead to problems with surgical procedures, increasing the risk of unused theatre time allocated for operations, resulting in poor performance, delays, change of patient order, change of instruments, or patients postponed due to lack of theatre time, as well as problems in perioperative process management. Errors and/or delays in weekly and daily scheduling penalize the synergistic efforts of healthcare staff as they strive to provide correct surgical organization and an optimal care experience for patients admitted to the IOR.

Several limitations must be taken into account. We can assume problems related to a lack of good scheduling belong to macro-areas of reference:

- Postponed patients generate problems with bed occupancy and room availability for newly scheduled incoming patients;
- Patients that are changed in the order list, or ineffectively scheduled generate increased TT and delays for the equipment preparations. According to Gottschalk et al. (2016), factors that affect TT include variables outside the OR, such as equipment failure/sterilization, and we expect these elements to improve with correct planning;
- Patients are not adequately studied before surgery: failure to forecast intubation and allergy problems.

It is important to note that the majority (53%) of total patients were not included in the WON. From this information, we deduct three possible causes of inefficiency in patient scheduling: operators delay WON generation as: (I) they consider it to be of low relevance, (II) organizational problems arise (lack of medium-term programming), or (III) technical issues arise (e.g., difficulties in programming types of patients). Each reason leads to different possible solutions. For example, the first case has managerial implications and can be solved through an internal review and the alignment of goals between hospital shareholders. The second condition requires additional training for operators, whereas the third is the most challenging to overcome. Indeed, it is important to note that some of the units included in the study manage case mixes of particular complexity, in which health conditions vary considerably, even in a short period, such as with oncologic patients. The scheduling of these interventions is subjected to greater organizational stresses precisely because of the rapid changeability of the patient's disease course. This leads to difficulties in long-term planning and the need for pre-admission checks close to the actual surgery to minimize the chances of the patient's clinical situation deteriorating.

As a further limitation, it should be noted that the observation period is only one month long. An extension would enable the study of variables with specific unit coverage, resulting in greater uniformity of surgery types.

5 Conclusion

As we have seen in our case study, proper adherence to scheduling led to better OR performance, at least in terms of start-time tardiness and turnover time. There is a lack of scientific evidence on the link between OR planning, scheduling, and resulting performance, and on which performance indicators are influenced. Such information is invaluable for OR managers striving to achieve correct planning by all operators involved, through the identification of affected performance areas.

Increased efficiency limits waste and promotes savings in terms of time and economic resources. A lack of scheduling can generate organizational, accessory, efficiency, patient, and employee well-being issues that affect the performance of operating theatres, hospital budgets, and surgical production. Therefore, hospital managers should focus on implementing good practices in the scheduling of patient procedures.

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