

# OPTIMIZING EFFICIENCY IN THE OPERATING THEATER

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## SUMMARY

**Background:** Operating theaters (OT) represent a critical intersection of hospital financial performance and clinical care quality, accounting for approximately 40% of institutional costs and 60-70% of revenue. Inefficiency in this high-stakes environment stems from complex interactions between patient factors, surgical team dynamics, and systemic hospital constraints. While financial investment is significant, the organizational ability to deliver intended outcomes remains the primary determinant of healthcare system efficacy.

**Objective:** This article aims to identify the multifactorial causes of OT inefficiency and provide a comprehensive framework for improvement using Key Performance Indices (KPIs) and Lean Six Sigma methodologies.

**Key Points:** Efficiency is quantified through specific metrics, including first-case start-time accuracy, turnover time (TOT), and case duration accuracy. Implementation of the DMAIC (Define, Measure, Analyze, Improve, Control) approach facilitates targeted interventions across the perioperative pathway. Preoperative strategies focus on reducing cancellations through improved communication and electronic health record integration. Intraoperative enhancements include surgical tray standardization, which can reduce instrument volume by up to 70%, and the utilization of "swim lanes" and "conductors" to synchronize team tasks. Data indicate that surgical team familiarity significantly impacts efficiency, with experienced teams achieving higher performance scores compared to those with no prior collaboration. Furthermore, parallel processing in anesthesia induction and surgeon-led change-over models can reduce TOT by over 50% without increasing complication rates.

**Conclusion:** Optimizing OT efficiency requires a systematic transition from sequential to parallel processing, standardization of surgical workflows, and the rigorous application of Lean principles to eliminate "Muda" (waste). Consistent monitoring of KPIs and fostering team cohesion are essential for maximizing surgical throughput and improving patient care outcomes.

## KEYWORDS

Efficiency, Organizational; Operating Rooms; Total Knee Arthroplasty; Quality Improvement; Workflow

## INTRODUCTION

Why increase Operating theater (OT) efficiency? Figure 1 depicts various factors that are impacted by OT efficiency. One vital aspect is the financial implications. However, the quality of delivered medical care is not just related to the amount of financial expenditure. Equally important is whether the healthcare system is well-organized and efficient, which means its ability to provide the intended outcomes, irrespective of the quantum of financial resources allocated, and even with a paucity of resources, in which case it is even more crucial [1-3].

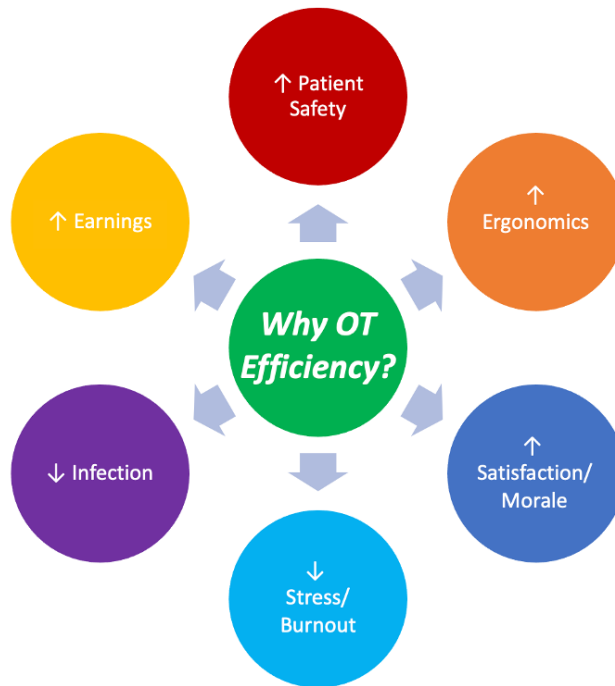


Figure 1: Factors affected by OT efficiency

Operating theaters (OT) are considered a very significant segment of both financial revenue and expenditure in most hospitals [4]. OTs account for about 40% of a hospital's costs and 60-70% of income [5], making it mandatory to improve the efficiency of OTs to enhance the surgical care provided within them to patients [4].

To improve the efficiency of the healthcare system in general and surgeries in particular, implementation of quality improvement programs such as the Six Sigma and the Lean systems (which were initially described for the manufacturing industry) into healthcare areas started in 1998 [6,7]. The two systems were combined into one - the "Lean Six Sigma". This included five stages known by the acronym DMAIC, which stands for Define, Measure, Analyze, Improve, and Control [7].

To assess whether the use of Lean and Six Sigma improves patient care in surgeries, a systematic review [1] was performed of 23 relevant studies for the following six outcomes: outpatient efficiency optimization, operating theatre efficiency improvement, lowering the rate of operative complications, ward-related harms reduction, decrease in mortality rates and avoidance of unnecessary expenses and length of stay. 88% of the included studies showed improvement in these outcomes, indicating that the implementation of Lean and Six Sigma in surgical practice may have a positive effect on improving patient care [1].

## 1. WHAT CAUSES OT INEFFICIENCY?

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The operating room is considered as a complex and dynamic environment with the possibility of various unpredictable situations; this results in multiple factors playing a role in OT inefficiency [4,5]. There are complex interactions involving all levels of surgical care: patients, caregivers, anesthesiologists, surgeons, nurses, administrative and facility staff [4,8]. The OR team must function as a cohesive unit despite hierarchical & status differences which influence communications & interactions.

### **Patient factors:**

Include unexpected changes or cancellations, violations of preoperative orders (such as fasting periods), missing medical clearances, and unexpected intraoperative findings that may change the strategy of the procedure [8].

### **Surgical team factors:**

Issues related to the type of the surgical procedure, surgeon level of expertise, familiarity of the surgical team with the instruments, and staffing factors, including delays to start as a result of overlapping procedures, poor communication, and improper OT flow [8,4].

### **Hospital system factors:**

Such as lack of real-time information, delay in equipment supply chains, sterilization processes, patient transportation, missing paperwork, and effective allocation and utilization of operating room block time for each patient, procedure, and surgeon [4].

## 2. HOW TO MEASURE OT EFFICIENCY USING KEY PERFORMANCE INDICES (KPIs)

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Efficiency is affected by multiple factors, some of which are quantitative (such as cancellation rates, change-over time, etc.), and some are qualitative (such as patient and staff members satisfaction, motivation). This makes it challenging to provide a single metric to measure OT efficiency [4]. Instead, a series of measures and metrics are suggested to evaluate OT efficiency [9,8]:

### **2.1 Procedure cancellation rate:**

Usually defined as same-day cancellations, could be classified according to the cause or the time, could be due to patient factors such as sudden illness, poor communication about fasting status, or missing medical clearance forms.

### **2.2 First case start-time accuracy:**

This is affected by OT and patient readiness. Some hospitals allow for a five-minute delay period for this metric. Incision time is mostly used as a more precise indicator of start time and patient readiness; however, this metric can be affected by factors related to the patient or the OT team (if personnel are missing when the patient is ready for incision) [10].

## 2.3 OT utilization:

This could be divided into two parts. The first is overall OT utilization - the time where activity is taking place in the OT, whether actual as surgeries or turn over. The second is the specific operative utilization - the total time between the first incision in the day till the last surgical case closure, (i.e., the overall period during which the operating room was open).

## 2.4 Off-hour's surgery:

When an urgent or emergent surgical case is added on, or if a procedure took longer time than expected.

## 2.5 Case duration accuracy:

This means appropriately assigning staff scheduling to the anticipated surgical time of the procedure for each surgeon; however, to find the appropriate intervention to improve this metric, we should distinguish between true throughput time (the interval between patient entry and exit) and turn over times (the interval between patient exit and next patient entry).

## 2.6 Turnover time: (TOT)

TOT is the interval between patient exit to the next incoming patient; this time is used for room cleaning, preparing equipment, and arrival of staff for the following procedure.

## 2.7 Turnaround time (TAT):

TAT is the time between closure and dressing of the previous case to the time of incision for the next case.

## 2.8 Unplanned closures percentage:

This could occur due to various reasons related to the surgical team or the equipment, such as closure for cleaning as required by infection control, malfunction of the headlamps, a deficit in the oxygen supply, etc.

## 2.9 Excess staffing costs:

This could result from several factors either by over-or under-utilization such as unexpected, prolonged cases, an extra unplanned case that gets added to the operative list, calling an additional nurse outside her duty and having to be paid an overtime salary.

## 3. HOW TO IMPROVE OT EFFICIENCY? ---

One of the key concepts upon which the Lean process is based is the avoidance of "Muda," which is a Japanese word that means wastefulness. The first step is to identify Muda during the different phases of the operative timeline. The next step is to reduce "Mudas" for which it is helpful to implement the DMAIC approach on different levels of perioperative care. For simplicity, it can be divided into pre-, intra-, and post-operative improvement areas. Whenever possible, one should identify steps that can be overlapped so as not to perform them sequentially but in parallel.

### 3.1 Preoperative KPIs Interventions:

This stage is an integral part of the patient's surgical pathway. It starts with the decision by the patient to have surgery, includes the preoperative assessment, and ends when the patient is transferred to the OT [1,11].

Several KPIs should be included for improvement during this stage:

#### 1. Unexpected Surgical Cancellations:

Reduction of cancellation is a very successful way of improving the PT efficiency, as it had been shown that unexpected elective surgery cancellation resulted in significant financial losses. A UK hospital reported a loss of about \$88 million for canceled surgeries [12]. Cancellation could be categorized into hospital (missing equipment), patient (surgery cancellation), and surgeon/staff-related factors (missing team member) [4]. Several strategies have been suggested to solve these issues, ranging from a designated preoperative anesthesia clinic, contacting patients through phone calls by nursing staff, and machine learning algorithms which could help to identify high-risk patients for cancellations [4,13]. Some suggested key factors for improvement are:

- a. Identify the leading causes of cancellation for each particular institution. This may differ from one hospital to another, and could be related to patient population, type of surgical procedures and hospital resources [4]. In one study, the authors reported that about 20% of patients missed their scheduled surgeries, and that more than 40% of the time, the hospital staff could not contact the patients or their caregivers [14]. This led to the improvements in how the hospital staff contacted the patients.
- b. Electronic health records provide a platform for measuring the patient data and to provide automated feedback; these data can help to identify the risk factors for patient cancellation. The collected data can help improving machine learning techniques to identify specific areas of intervention to lower the cancellation rates [13].
- c. Clear communication: An example of improper communication is failure to maintain NPO status before surgery, leading to increase cancellation rates. 15% of the total surgical cancellations were due to failed NPO status, and 80% of these were due to improper communication [14]. This led the authors to implement a multi-modal strategy using a standardized sheet and infographics clearly indicating the time to start fasting and what is allowed, and to use an automated message service as a reminder. These maneuvers led to a 17% improvement in the OT utilization [14].

#### 2. Case scheduling:

This could be a complicated task to perform. It could be performed on the basis of previous historical times for a specific surgeon. However, it is better to be calculated based on service-specific times; it should balance between maximizing OR utilization and maintaining team cohesiveness and continuity. Effective scheduling will motivate the surgical team, save time, and improve patient's satisfaction [8].

#### 3. Inpatients:

Automated multiple steps involving patient preparation and efficient transfer to the OT area can help remove the difficulties resulting from unnecessary phone calls between the circulating nurse and other OT staff. Inpatient preoperative anesthesia evaluation the day before surgery is essential, especially for patients with multiple comorbidities [8].

## 3.2 Intraoperative KPIs Interventions:

This phase starts as soon as the patient enters the OT and extends till the patient is transferred to the recovery room or the post-anesthesia care unit (PACU). This complex phase necessitates the cooperation between all surgical team members, which benefits from small steps such as team briefing or “huddle” and a surgeon acting as the team leader.

### 1. Redesigning Operative Workflow:

Improving the intraoperative surgical workflow will improve OT efficiency by reducing time and wastage of resources. The surgeon must have a clear plan. ‘Process Mapping’ is useful to achieve improved workflow of surgical procedures through outlining and revising each step of the surgical procedure with the surgical team. This helps in decreasing staff uncertainty and improving anticipatory involvement. In fact, process mapping has been shown to reduce operative time by 12 to 20 % in some studies [15,16]. Another strategy is the implementation of a standardized case cart and surgical setup, which help in decreasing the operative time by about 20% [17]. Using evidence-based medicine can help abandon methods which have been shown to be of no value but may add to unnecessary wastage of time (tourniquets, drains, etc).

### 2. First Case Start Time:

A key target to improve OT efficiency is the consistent start time of the first procedure. 50 to 80% of the first cases in tertiary care hospitals were delayed for a period as long as 30 minutes, thereby reducing operative room efficiency and increasing costs [18,19]. This delay is often preventable and mostly resulted from the unavailability of the surgeon or one of the staff members, delayed patient registration, or transportation issues [20]. Introduction of the Six Sigma and Lean strategies can improve the percent of on-time first-case starts. The DMAIC approach was useful in identifying barriers against bringing the patient on time for the first procedure and doubled the percent of on-time first starts from 49 to 92% [18]. Also, improved communication and team briefings before each operative case between surgeons, anesthesiologist, nursing staff, and technicians, significantly improved the first case on-time starts [21].

### 3. Operative Case Duration Accuracy

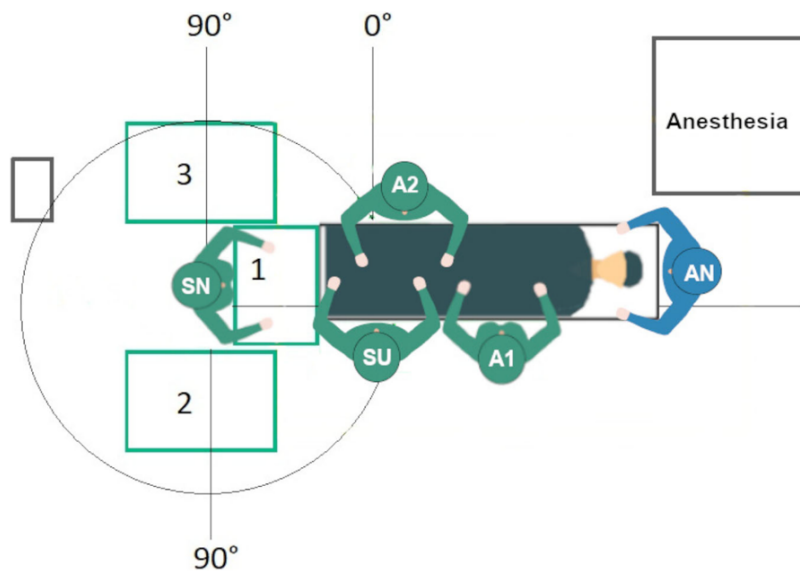
OT under- or over-utilization could result from an improper estimation of the operative case duration [4]. Depending solely on the surgeon to estimate the operative time necessary for a surgical case led to about 75% inaccuracies in reporting the operative time [22]. An innovative strategy used to fix this problem is implementing artificial intelligence and machine learning; by gathering the available data regarding patients' demographic characteristics, preoperative milestones, and hospital logistics, a machine learning algorithm was developed, and this reduced scheduling inaccuracies by 70% [23].

### 4. Surgical Tray Standardization:

For each surgical procedure, standardizing and reducing the surgical instruments could decrease the cost, set up time, and improve the turnover time leading to improving OT efficiency [4]. 13 to 22% of the instruments in the surgical trays are used; the remaining unused instruments represent a waste of sterilization cost [24]. Implementing the Lean process in this step enabled the reduction of number of instruments for each procedure by 19 to 70% [25,26].

### 5. OT setup:

The optimal setup for a TKA is depicted in Figure 2. This enables freedom of movement for the scrub nurse, visibility of operative field, reduced instrument handover time, correct ergonomics and posture, correct staff flow and maintains sterility. The scrub nurse should be familiar with the instruments and their usage, assembly and disassembly. Also, the layout of instruments should be such as to minimize handover time.



Neumann et al. *BMC Medical Informatics and Decision Making* (2020) 20:145

Figure 2: Optimum OT setup for TKA

## 6. Surgical Team Standardization:

Working with the same OT staff who are familiar with the procedure being performed and as per surgeon preference showed a positive effect on OT efficiency. The operative time decreased by up to 47 minutes [27,28]. It is important that the surgeon's gaze should not leave the operative field. Thus, the scrub nurse must be positioned correctly (below) and the instruments passed appropriately as they will be held by the surgeon.

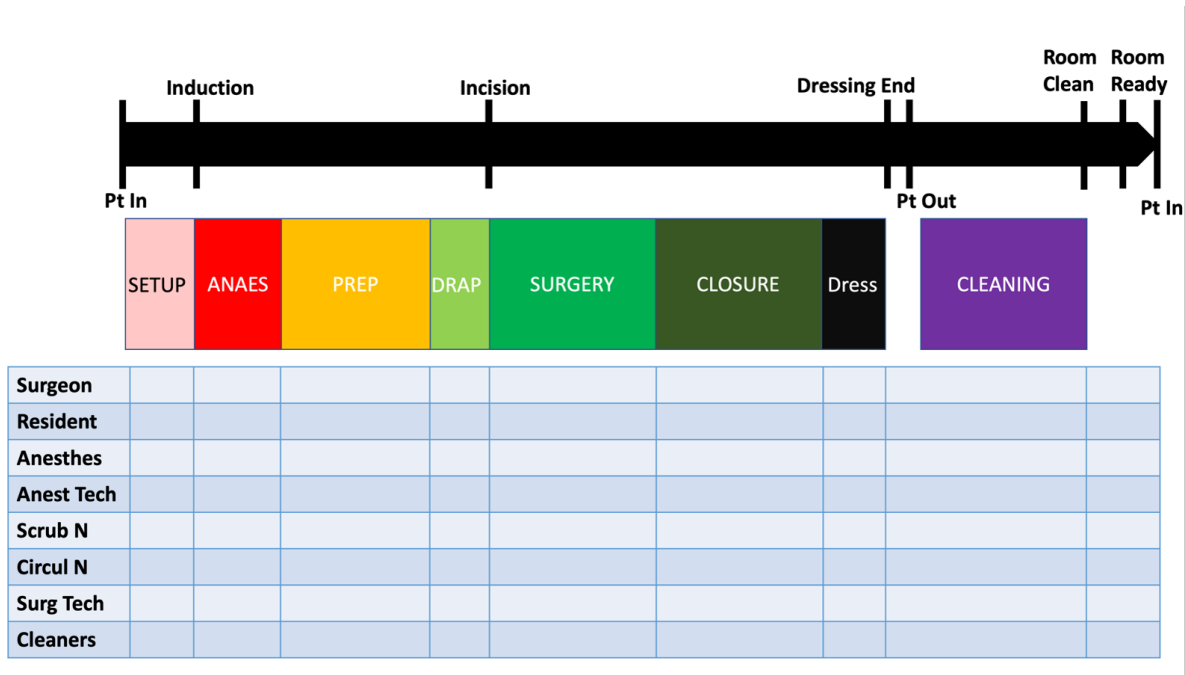
To examine the surgical team efficiency during primary total knee arthroplasty (TKA), Michnick et al. videotaped ten TKA surgeries. They found that the most time-consuming steps were wound closure and performing distal femoral cuts. Overall, they reported 570 delaying events with a mean of 57 per surgery. Least frequently, the surgeon was handed the wrong instrument (0.4 /case); most commonly, the surgeon diverted his attention from the surgical field, (35.2 times/ case). Surgical team experience correlated positively with efficiency: the mean score of surgeries of teams with 5 years' experience was 81.2%, vs. only 71.9% when the surgical tech had never operated with the surgeon previously. They concluded that the team experience is an important factor affecting OT efficiency during TKA surgeries [29]. For new teams, usually at the start of Fellowships, the senior author organizes saw-bone workshops for the entire team to familiarize them with the flow, instruments, and their usage.

## 7. 'Conductor':

The senior author has used a method of appointing a 'Conductor' to announce the next step a little in advance so that the person who is to implement it is ready to do so at the right time without any delay. This individual may be a Fellow, Tech, Assistant surgeon, or someone among the team who is totally familiar with all the surgical steps. This is more valuable when the teams vary. This concept allows the surgeon to single-mindedly focus on the surgery. The conductor changes to another team member after a few months.

**8. Swim lanes:**

Mudas can be minimized or avoided by developing swim lanes for each member of the team, so each one knows when to perform his or her task in time. (Figure 3)



**Figure 3: 'Swim lanes' for each team member**

**9. Real-Time Locating Systems:**

To identify the deficiencies in the OT, a real-time locating system using Bluetooth technology could also be used to track and visualize the OT flow and process; this system could provide automated responses related to stock insufficiencies [4]. Implementing this real-time locating system to produce an automated alert indicating patient readiness for anesthesia induction, Yeoh et al. reported a significant decrease in the duration between patient arrival and anesthesia induction leading to an overall operative time reduction [30].

**10. OT Turnover Time**

Turnover time (TOT) is the time between patient exiting OT to the time the next patient enters the OT. Turnaround time (TAT) is the time between closure and dressing of the previous case to the time of incision for the next case. Surgeons always complain about the time wasted between cases! During a usual operative day, a surgeon spends less than 50% of the time operating, Increased TOT resulted in an increase in the costs and a decrease in patient satisfaction [32]. In an efficient OT, average turnover time ranges from 15 to 28 minutes [3,33]. If we round it off to 20 minutes, extra 100 minutes can be saved in a standard five cases list, enabling time for an extra/emergency case to be operated upon [34]. One of the main barriers against improving this metric is the difference in surgical team members' motivations, as for example, surgeons are urged to increase their surgical volume while the anesthesiologist is being paid hourly [35]. Implementation of the Lean process has shown a great improvement regarding the turnover time; Cerfolio et al. reported decreasing the median operating room turnover time from 37 to 14 min. They allowed the anesthesiologist to start their processing earlier by meeting the next patient and starting their intravenous line and consent process; they improved workflow issues with the circulator; they eliminated unnecessary travel time needed to get supplies by preparing a case cart for the whole day filled with the required supplies. Another strategy to improve TOT is the availability of a well-equipped post-anesthesia care unit (PACU) for recovery [4]. It should be well-prepared and have enough beds to receive patients. By proper planning - predicting the length of the surgery, and length of stay in the PACU one can improve OT efficiency. Implementing a machine learning algorithm for prediction of PACU time required for each surgical procedure reduced the total stay by 76% which led to significant cost savings [37].

#### **11. Parallel processing:**

This implies having a separate room for anesthesia induction and/or emergence from anesthesia; this can save up to 60 minutes. However, this method had been criticized for leading to more staffing requirements with an increase in cost [38,33]. Mizumoto et al. carried a single-blinded, randomized controlled study to examine a working strategy aiming at improving TOT. They compared a surgeon-led team using parallel processing (single surgeon) versus routine patient change-over model (four surgeons). The authors evaluated the difference in TOT between both strategies, the overall differences in complications, and the incidence of operative case cancellations. Across 1265 patients subjected to minor and major general surgery procedures, the overall median TOT was  $17.9 \pm 3.7$  min. The surgeon-led team-based strategy showed a significantly lower median TOT of  $12.1 \pm 5.4$  min ( $p < 0.001$ ), representing a 58% reduction in median change-over-time compared to the other strategy. Also, no cases were canceled in the first strategy compared to 37 in the other strategy due to lack of time, and there was no difference in complication rates. The authors concluded that a surgeon-led team-based model improved the change over time without the need for an extra cost, staff members, or increase the number of operative theaters [34].

### **3.3 Postoperative KPIs Interventions:**

This phase starts immediately after completion of surgery, with the patient being transferred to PACU, and thereafter being transferred to the inpatient area. Clearly, factors such as preparedness of the PACU, availability of transport, beds and readiness of the inpatient bed will also impact the time the patient is needlessly detained in the OT.

## **4. FURTHER STRATEGIES TO IMPROVE OT EFFICIENCY RELATED TO THE SURGICAL TEAM**

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Teamwork, Motivation, Open Communication, and Staff Members' Involvement.

Collaboration between OT personnel is paramount in the presence of a leader for efficiency, it is essential to have clear communication, respect, accountability, and everyone should be actively involved in taking care of patients, irrespective of the hierarchy. The senior author also insists that all instructions are acknowledged loudly and clearly so that the surgeon knows that the action has been performed without having to take his gaze away from the operative field.

TOT and OT efficiency could be significantly improved by the active involvement of the surgical registrar; early arrival of the registrar, his or her active involvement in the patient nonoperative care, and the open communication with the surgical team members [3]. Some studies show that in a teaching facility, with the involvement of more junior staff and surgical and anesthetic trainees, there may be an increase in the operative and TOT [1,39,40]. Mizumoto, et al., however, reported that implementing a structured strategy combined with careful supervision of junior staff showed a positive effect on patient TOT [34]. For a junior surgeon during the start of his training, thorough exposure to the OT environment is paramount, the need for leadership skills development is also important, and having good communication with other team members had its positive effect on team cohesion and motivation, which eventually will lead to improved OT efficiency [21].

Moreover, the active involvement of the trainees in parallel processing allows him/her to communicate more efficiently with the surgical team members, become involved in the process of describing and observing the surgical steps, and to be able to identify problems within the process. In the future, this experience will allow the trainee to be more confident in coordinating the general flow within the OT aimed at improving efficiency [34].

## 5. GUIDELINES FOR OT EFFICIENCY

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Fong et al. [41] provide some guidelines for OT efficiency based on their systematic review. They have divided these into three main categories based on the scale of intervention:

### 1. Small scale:

Which could be applied to a single surgeon or small groups, and these could be rapidly implemented

- a. Redesigning the surgical workflow: including the use of surgical checklists, parallel processing, process mapping, and staff briefing.
- b. Instruments and supplies standardization: by removing unnecessary or rarely used instruments.
- c. Surgical team huddles: pre-and post-operative huddles, which could improve the workflow and reduce errors.

### 2. Medium scale:

Which could be applied to larger surgical groups

- a. Checklists: this could be used intraoperatively to reduce any error in the routine surgical cases and could be used outside the OT to hasten the patient flow.
- b. Teaming: Working with a familiar, fixed team improved operative speed, communication, and safety with secondary improvement in quality.

c. Data tracking: this is important to identify the reasons leading to OT insufficiency and promote transparency.

d. Costs Awareness: surgical team, including surgeons and nursing staff, should be educated regarding the financial impact of disposable items costs, and the financial impact of OT time wastage

### 3. Large scale:

This involves cooperation between different institutions with the need for capital investment.

a. Supply-chain management: as examples, the minimization of stock shelving by removing unused instruments, and simplifying the stockroom order to speed up the localization of supplies.

b. Specialization: by assigning a specifically trained team for a specific surgical procedure.

c. Space redesign: by what is called an 'intelligent design' which helps to minimize movement inside the OT (patient, surgeon, and nursing staff). Although this step needs massive investment, it is justified by the expected returns after improving the flow with lowering of the intraoperative time lost.

d. Parallel processing: this strategy will help in decreasing the time lost between cases.

## CONCLUSION

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- Measure Key Performance Indices (KPIs)
- Establish & follow plans, protocols, process mapping, manuals, and checklists
- Identify and avoid Muda, overlapping steps where feasible
- Efficient OR setup, standardization of carts, & correct instrument handling and passing
- Attention, anticipation, and acknowledgment by the team
- Better teamwork by briefings, 'huddles', 'Swim lanes', checklists, workshops, and appointing a 'Conductor'

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