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Original article

Compared efficiency of trauma versus scheduled orthopaedic surgery operating rooms in a university hospital

Thibaud Rodriguez*, Aurélie Wolf-Mandroux, Jennifer Soret, Louis Dagneaux, François Canovas

Département de chirurgie orthopédique et traumatologie, unité de chirurgie du membre inférieur et du rachis, hôpital Lapeyronie, CHRU Montpellier, 351, avenue Gaston-Giraud, 34295 Montpellier cedex 5, France

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ABSTRACT

Background: The objective of this study was to contribute to an OR efficiency optimisation effort by comparing a trauma OR versus a scheduled surgery OR in a lower limb orthopaedic surgery department.
Hypothesis: The main hypothesis is that efficiency is lower in the trauma OR than in the scheduled surgery OR. The secondary hypothesis is that efficiency of the trauma OR is lower during weekends.
Material and methods: This prospective study was conducted in 2016 in the orthopaedic surgery department of a university hospital. Patients were divided into three groups based on whether they underwent scheduled surgery (SchOS), trauma surgery on a weekday (TSwk), or trauma surgery on a weekend (TSwkend). Actual OR occupancy time, allocated OR block time (BT), OR occupancy rate, patient entrance-to-incision time, incision-to-closure time, closure-to-post-anaesthesia care unit (PACU) entrance time, and clean-up/set-up time (T4) were measured.
Results: We included 691 patients in the SchOS group, 819 in the TSwk group, and 327 in the TSwkend group. OR efficiency was lower in the TSwk group compared to the SchOS group (occupancy rate, 86% vs. 88%; $p = 10^{-4}$). All occupancy time components were longer in the TSwk group. However, each component accounted for similar total occupancy time proportions in the two groups, except for clean-up/set-up time, which was longer in the TSwk group ($p < 0.05$). On average, entrance-to-incision time accounted for 31%, incision-to-closure time for 34%, closure-to-PACU time for 18%, and clean-up/set-up time for 17% of total occupancy time. Efficiency was lower in the TSwkend group than in the TSwk group (occupancy rate, 75% vs. 86%; $p = 10^{-4}$). The TSwkend group had shorter entrance-to-incision and incision-to-closure times ($p < 0.05$) and a nearly 10% longer clean-up/set-up time ($p < 0.05$).
Conclusion: Efficiency of the trauma OR, although lower compared to the scheduled orthopaedic surgery OR, was nevertheless satisfactory as assessed based on standard indicators. Of the four total occupancy time components, the first three accounted for similar proportions of the total; differences occurred only for clean-up/set-up time. Efforts to improve OR efficiency should focus on arrival of the first patient and turnover time.
Level of evidence: II, prospective cohort study.

1. Introduction

In France, the National Hospital Expert Assessment and Audit Agency (mission nationale d'expertise et d'audit hospitalier, MEAH) developed operating room (OR) efficiency indicators about a decade ago, based on work by Strum et al. [1]. These indicators provide a detailed picture of the times during which an OR is used for specific activities, thus identifying areas for improvement and allowing the implementation and evaluation of optimisation measures [2]. Our everyday practice suggests considerably lower efficiency of trauma ORs compared to scheduled surgery ORs in orthopaedic departments.

The objective of this study was to contribute to an OR efficiency optimisation effort by comparing a trauma OR and a scheduled surgery OR in a lower limb orthopaedic surgery department. The main hypothesis was that efficiency was lower in the trauma OR than in the scheduled surgery OR. The secondary hypothesis was that efficiency of the trauma OR was lower during weekends.

* Corresponding author.
E-mail address: zed34490@hotmail.com (T. Rodriguez).

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2. Material and methods

A prospective study was conducted in 2016 in our department of trauma and orthopaedic surgery of the lower limb. As orthopaedic surgery is becoming increasingly specialised, our university hospital has created two different orthopaedic surgery departments, one for the lower limb and the other for the upper limb. Each of these two departments has dedicated ORs for trauma surgery and for scheduled surgery. We included patients who underwent lower limb surgery in the trauma OR or in the scheduled surgery OR with the longest block times.

Patients were divided into three groups based on whether they underwent scheduled orthopaedic surgery (SchOS), trauma surgery on a weekday (TSwk), or trauma surgery on a weekend (TSwkend). The block times extended from 7:30 am to 6:30 pm in the SchOS and TSwk groups. At other times, only emergency ORs were available. On weekends and holidays, an emergency OR was available around the clock; this room was used for the patients in the TSwkend group.

Time data for each surgical procedure were collected from the OR log forms and entered into Dxcare® software (Medasys, Le Plessis Robinson, France). During each procedure, the circulating nurse entered the following data into the OR log form: clean-up/set-up time, time of patient entrance, time of anaesthesia induction, time of the incision, time of wound closure, wound dressing time, and time of patient exit. These data then served to compute the OR efficiency indicators. We excluded patients who were moved from one OR to another during the same procedure and those who had surgery off hours, when staff numbers were lower.

We determined the first case start time and the time of the first incision. The following MEAH core indicators and patient processing indicators were computed (Fig. 1):

- total occupancy time, as the time between patient entrance into the OR and the end of clean-up and set-up for the next patient;
- allocated block time (BT), as the time from entrance of the first patient to exit of the last patient;
- OR occupancy rate, as the total of the occupancy times for all patients divided by the block time;
- entrance-to-incision time, as the time required, after patient entrance, for anaesthesia induction, patient installation, and draping in preparation for surgery;
- incision-to-closure time, as the duration of the surgical procedure;
- closure-to-post-anaesthesia care unit (PACU) entrance time, as the time needed, after wound closure, to fashion the dressing, transfer the patient from the table, and move the patient out of the OR and into the PACU;
- clean-up and set-up time needed to ready the OR for the next patient;
- and readiness-to-entrance time (T5), as the time between the end of clean-up/set-up and entrance of the next patient.

The statistical analyses were performed using SPSS software (IBM, Armonk, NY, USA). Student's *t* test was applied to compare the SchOS and TSwk groups and the TSwk and TSwkend groups.

3. Results

We included 691 patients in the SchOS group, 819 in the TSwk group, and 327 in the TSwkend group. Table 1 reports the results.

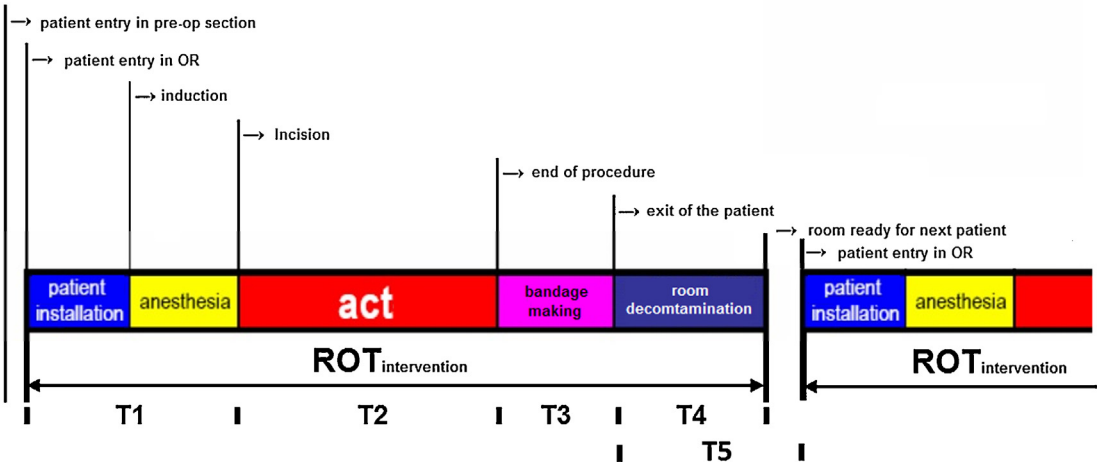

Fig. 1. Definition of total occupancy time.

Table 1
Mean values of the operating room efficiency indicators.

	Scheduled surgery $n = 691$	Trauma surgery on weekdays $n = 819$	Trauma surgery on weekends $n = 327$
Block time	8h26 ± 2h24	9h47 ± 1h38	10h55 ± 4h09
Total OR occupancy time	2h17 ± 1h13	2h43 ± 1h38	2h11 ± 1h03
Occupancy rate	88.4% ± 7%	85.6% ± 8%	75.7% ± 15%
Time of first patient arrival	7h32 ± 0h15	08h11 ± 0h45	09h05 ± 0h49
Incision of first patient	08h33 ± 0h18	09h16 ± 0h48	10h11 ± 0h51
Entrance-to-incision time	0h46 ± 0h19	0h55 ± 0h21	0h39 ± 2h03
Incision-to-closure time	01h05 ± 0h55	1h14 ± 1h42	0h42 ± 2h06
Closure-to-PACU time	0h27 ± 0h44	0h36 ± 1h11	0h31 ± 01h17
Clean-up/set-up time	0h17 ± 0h25	0h28 ± 0h25	0h58 ± 1h08
Readiness-to-entrance time	0h27 ± 0h25	0h40 ± 0h26	1h11 ± 1h16

OR: operating room; PACU: post-anaesthesia care unit.

3.1. Comparison of the scheduled surgery (SchOS) and weekday trauma surgery (TSwk) groups

The OR occupancy rate was 2.8% lower in the TSwk group than in the SchOS group ($p = 10^{-4}$). The OR occupancy time for each patient was significantly higher in the TSwk group than in the SchOS group. This increase started with the first patient, who arrived 38 minutes later after the operating room opening time in the TSwk group than in the SchOS group ($p = 10^{-4}$).

The breakdown of total OR occupancy time, expressed as percentages, was as follows (Fig. 2): entrance-to-incision time, 32.2% in the SchOS group and 31.9% in the TSwk group ($p = 0.933$); incision-to-closure time, 37.4% in the SchOS group and 36.8% in the TSwk group ($p = 0.247$); closure-to-PACU time, 17.6% in the SchOS group and 18.2% in the TSwk group ($p = 0.329$); and clean-up/set-up time, 12.7% in the SchOS group and 15.1% in the TSwk group ($p = 10^{-4}$). The readiness-to-entrance time was 13 minutes longer in the TSwk group than in the SchOS group.

3.2. Comparison of the weekday (TSwk) and weekend (TSwkend) trauma surgery groups

The occupancy rate was 9.9% lower in the TSwkend group than in the TSwk group ($p = 10^{-4}$). The entrance-to-incision and incision-to-closure times were shorter in the TSwkend group, whereas the closure-to-PACU time was similar in the two groups. The lower occupancy rate in the TSwkend group was related to a 31-minute longer readiness-to-entrance time ($p = 10^{-4}$). First case start time was nearly 1 hour later in the TSwkend group than in the TSwk group ($p = 10^{-4}$).

The breakdown of total OR occupancy time, expressed as percentages, was as follows: entrance-to-incision time, 28.8% in the TSwkend group and 31.9% in the TSwk group ($p = 10^{-4}$); incision-to-closure time, 27.6% in the TSwkend group and 36.8% in the TSwk group ($p = 10^{-4}$); closure-to-PACU time, 19.2% in the TSwkend group and 18.2% in the TSwk group ($p = 0.411$); and clean-up/set-up time, 24.3% in the TSwkend group and 15.1% in the TSwk group ($p = 10^{-4}$). Readiness-to-entrance time was 31 minutes longer in the TSwkend group than in the TSwk group ($p = 10^{-4}$).

4. Discussion

Although lower than for the scheduled surgery OR, efficiency of the trauma OR was acceptable as assessed using standard indicators. The most widely stated objective is an occupancy rate of at least 80%. The lower efficiency of the trauma OR on weekends compared to weekdays was due to a 31-minute longer time from OR readiness to next patient entrance. All the components of total OR occupancy time were longer for the trauma OR: first case start was later and the times needed for induction, surgery, patient exit, and entrance of the next patient after clean-up/set-up were significantly longer. Nevertheless, when expressed as a percentage of total occupancy time, each of these components was similar across the groups, perhaps due to factors related to the complexity of the surgical procedures. On average, entrance-to-incision time was 31%, incision-to-closure time 34%, closure-to-PACU time 18%, and clean-up/set-up time 17% of the total occupancy time.

Trauma surgery is performed on an emergency basis and the required organisational resources are therefore more difficult to predict. The result is a risk of flaws in preparation or coordination that may translate into time being wasted or friction developing among teams [3]. The main source of such flaws is faulty communication, for instance regarding the order of the patients, the equipment used, or the type of installation [4–7]. Each trauma OR in our department has a display board that shows the identities of the patients awaiting surgery, as well as their ward, their diagnosis, and the equipment needed for their procedure.

The order of patients on a given day is determined by the surgeon who was on duty the night before, in order to facilitate good organisation. Nevertheless, transfer of the first patient to the OR may be delayed due, for instance, to the anaesthesiologist visit not yet having been performed or to the required equipment not yet being available.

4.1. Patient arrival

In our study, the incision was performed 42 minutes later in the trauma patients compared to the patients undergoing scheduled surgery. Thus, despite our organisational efforts, the first case start-time remained suboptimal. Any delay in the first case start time delays all the other procedures scheduled for the same day.

We believe that many measures can be taken to optimise the first case start time:

- the best patient to be the first case of the day should be correctly identified;
- the OR start time should be clearly defined and written in the OR policy statement;
- coordination between all staff members involved in carrying out the first procedure should be optimised;
- limiting resources should be taken into account (e.g., an orderly cannot transfer two patients at the same time) and;
- awareness should be raised among OR staff members about the need to follow the rules for the morning OR start.

Causes of delays, which may be multifactorial, can then be identified, either with the goal of making adjustments or to determine the steps that should be taken when the rules are not followed.

4.2. Induction

Trauma patients are potentially more vulnerable, as they are usually elderly and/or have multiple injuries. The anaesthesia may therefore be longer and more difficult to perform (spinal anaesthesia, multimodal anaesthesia, or patient coming from the intensive care unit). Furthermore, patient installation may require greater caution or be more complex (en-bloc transfer, traction table, or prone position).

Both the induction and the installation times have become longer over the years, in part due to safety considerations (monitoring, bispectral index, multiple venous lines), efforts to maximise patient comfort (peri-nervous anaesthesia, installation), and the use of various pieces of equipment (arthroscopic or minimally invasive surgery, radiography devices) [8]. Completing a preoperative checklist does not influence any of these preliminary steps and has

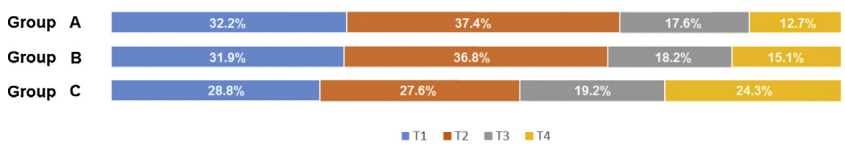

Fig. 2. Distribution of the components of total occupancy time in the three groups.

been shown to decrease organisational problems [9], as well as the risk of complications [10].

The entrance-to-incision time was similar in all the groups (32% of total occupancy time) and was about the same as the incision-to-closure time (35%). The entrance-to-incision time was 25% in a study by Madni et al. of a burn centre OR [11] and 23% in a heart surgery study by Luthra et al. [12].

The entrance-to-incision time, also known as the knife-to-skin time [12] has been used as a marker of OR efficiency. Analysing the various events that occur between patient entrance and the incision may lead to management improvements associated with a shorter entrance-to-incision time [13,14]. Choices regarding the anaesthesia protocol have a non-negligible effect on streamlining patient flow from one step to the next of the surgical pathway. A number of factors deserve to be considered. More specifically, availability of a pre-induction room may allow certain tasks to be predicted and some types of induction (e.g., local and regional anaesthesia) to be performed during OR clean-up and set-up.

4.3. Operative time (incision-to-closure time)

Prediction of the incision-to-closure time may be less accurate in trauma than in scheduled orthopaedic surgery, given the higher likelihood of unexpected difficulties during the procedure and or errors in the material prepared. Underestimation of the incision-to-closure time results in the next patient's procedure being delayed, whereas on-time procedures are the rule in scheduled orthopaedic surgery.

The incision-to-closure time (procedure time, operative time) is the parameter most widely criticised by OR staff members [12,15]. In our study, the incision-to-closure time accounted for less than half of the total OR occupancy time.

It has been suggested that trauma ORs should be staffed by dedicated trauma surgery teams to improve both patient management and OR management [16,17]. This practice occurs in some countries but is rare in France [18].

4.4. Anticipate preparation of the material

The resources, particularly the material, needed for each procedure must be identified. Correctly forecasting material preparation requirements contributes to streamline the surgical programme. Ensuring practice uniformity also facilitates preparation of the material and management of the inventory.

4.5. Patient exit

When possible, patients should be awoken in the PACU rather than in the OR in order to free up the OR sooner, thus allowing the next procedure to start earlier.

4.5.1. Turnover (patient out of room to next patient in room)

4.5.1.1. Optimise biocleaning. Biocleaning between two procedures must be carried out by staff identified according to protocols validated by the hospital's nosocomial infection control committee, according to the needs of each surgical speciality and each type of procedure. The clean-up/set-up time between two procedures should be evaluated regularly to identify any differences compared to predictions, which may translate into programme delays and longer patient waiting times [19].

4.5.1.2. Calling the next patient. Stringent regulation improves the flow from one procedure to the next and increases the OR occupancy time. The regulator must be able to monitor the progress of the programme in the various ORs in real time.

4.5.1.3. Patient transport. Optimal patient transport by the hospital orderlies improves patient flow, particularly during periods of peak activity, i.e., usually at the start of the day or around noon. Reappraisals may be in order to evaluate orderly assignments depending on peak activity times, as well as orderly call modalities. Optimising the organisation of patient transport can decrease the patient waiting times at OR entrance and exit. Having the patients walk to the OR when possible for scheduled surgery, particularly at the upper limb, is effective and optimises the use of orderly time [20].

Failure to call and transport the next patient in time increases the gap between two surgical procedures. The procedures normally performed in the pre-induction room (local and regional anaesthesia, intravascular line placement) are then performed in the OR. The result is an increase in surgeon idling time, as well as in total OR occupancy time, with no decrease in occupancy rate. This form of dysfunction is therefore not clearly captured by the standard OR efficiency indicators.

Involvement of the medical and non-medical staff affects the efficiency of trauma OR utilization. In contrast to scheduled surgery, trauma surgery is performed without a pre-planned programme and the staff may therefore be less attentive to streamlining connections between sequences, particularly as the trauma OR is open around the clock and the staffs works in shifts.

Thus, each of the occupancy time components is longer in trauma surgery than in scheduled surgery. Nevertheless, in relative terms, OR occupancy percentages differ little between these two types of OR.

The main points amenable to efficiency improvements are on-time arrival of the first patient and the entrance-to-incision time. During weekends, the time from OR readiness-to-entrance of the next patient should be optimised to maximise OR utilisation. To ensure that the first trauma patient arrives at the OR on time, we believe the best approach consists in using the same method as for scheduled surgery ORs. Thus, the request for first patient transport to the OR should be entered into the software on the previous evening by the nurse on duty, according to the choice made by the surgeon and in agreement with the anaesthesiologist. If the order of the patients must be changed (for instance because of a diaphyseal fracture in a patient admitted during the night), the surgeon can make a request to the nurse who can then change the order, plan the transport of the new patient, and inform the anaesthesiologist that the patient requires a preoperative visit.

Thus, all those involved are informed of the characteristics of the first patient and can check that no component has been overlooked (e.g., blood tests, material, preoperative computed tomography). Patient transport to the OR can then be reliably ensured.

By making this information available and training the surgical teams, practices can be improved in a way that increases efficiency and patient management in both trauma and scheduled surgery [19].

5. Conclusion

Efficiency of the trauma OR was lower compared to the scheduled surgery OR but was nevertheless satisfactory, with a greater than 80% occupancy rate. Although each component of the occupancy time was longer in trauma surgery, the proportion of the occupancy time contributed by each component was similar across groups. Efforts to improve efficiency may need to focus on starting the first case on time and on shortening the time from OR readiness-to-entrance of the next patient.

Disclosure of interest

The authors declare that they have no competing interest.

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Contribution of each author

TR: study conception and design; data acquisition, analysis, and interpretation; statistical analysis; manuscript drafting; and final approval of the version to be submitted.

AW: study conception and design; data acquisition, analysis, and interpretation.

JS: final approval of the version to be submitted.

LD: data analysis and interpretation; critical manuscript revision for important intellectual content; final approval of the version to be submitted.

FC: study conception and design; final approval of the version to be submitted.

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