Journal of Critical Care (2008) 23, 222–226

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Journal of Critical Care

Fewer intensive care unit refusals and a higher capacity utilization by using a cyclic surgical case schedule

Mark Van Houdenhoven MSc[a,b], Jeroen M. van Oostrum MSc[a,b,*], Gerhard Wullink PhD[a,b], Erwin Hans PhD[c], Johann L. Hurink PhD[d], Jan Bakker MD, PhD[b], Geert Kazemier MD, PhD[a,e]

[a]*Department of Operating Rooms, Erasmus University Medical Center, The Netherlands*
[b]*Department of Intensive Care, Erasmus University Medical Center, 3000 CA, Rotterdam, The Netherlands*
[c]*Department of Operational Methods for Production and Logistics, School of Management and Governance, University of Twente, 7500 AE, Enschede, The Netherlands*
[d]*Department of Electrical Engineering, Mathematics and Computer Science, University of Twente, 7500 AE, Enschede, The Netherlands*
[e]*Department of Surgery, Erasmus University Medical Center, 3000 CA, Rotterdam, The Netherlands*

Keywords:
Intensive care unit;
Master surgical schedule;
Surgical case;
Health care efficiency

Abstract

Purpose: Mounting health care costs force hospital managers to maximize utilization of scarce resources and simultaneously improve access to hospital services. This article assesses the benefits of a cyclic case scheduling approach that exploits a master surgical schedule (MSS). An MSS maximizes operating room (OR) capacity and simultaneously levels the outflow of patients toward the intensive care unit (ICU) to reduce surgery cancellation.

Materials and Methods: Relevant data for Erasmus MC have been electronically collected since 1994. These data are used to construct an MSS that consisted of a set of surgical case types scheduled for a period or cycle. This cycle was executed repetitively. During such a cycle, surgical cases for each surgical department were scheduled on a specific day and OR. The experiments were performed for the Erasmus University Medical Center and for a virtual hospital.

Results: Unused OR capacity can be reduced by up to 6.3% for a cycle length of 4 weeks, with simultaneous optimal leveling of the ICU workload.

Conclusions: Our findings show that the proposed cyclic OR planning policy may benefit OR utilization and reduce surgical case cancellation and peak demands on the ICU.
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1. Introduction

Mounting health care costs force hospital managers to maximize utilization of scarce resources and simultaneously improve access to hospital services. Efforts are therefore directed at developing planning methods that may deal with these seemingly conflicting objectives [1].

* Corresponding author. Department of Operating Rooms, Erasmus University Medical Center, P.O. Box 2040, 3000 CA Rotterdam, The Netherlands. Fax: +31 10 463 4035.

E-mail address: j.vanoostrum@erasmusmc.nl (J.M. van Oostrum).

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doi:10.1016/j.jcrc.2007.07.002

Typically, Dutch hospitals use a block planning approach for surgical scheduling [2]. In this approach, surgeons of various departments plan their patients in blocks of operating room (OR) time assigned to their specific department. The method of planning largely determines the utilization of the available OR capacity and thus the efficiency of the OR department. Implicitly a substantial part of the surgical schedules is basic and performed in a cyclic manner. In addition, the surgical schedule determines the daily number of patients flowing from the OR to the intensive care unit (ICU) postoperatively and hence influences surgical and nonsurgical patients' access to the ICU. Scheduling surgical cases without taking into account the inherent ICU or ward occupancy will result in peak demands on these hospital resources. Such peak demands may lead to bed shortages and thus to cancellation of surgical cases or refused ICU admissions for other indications [3]. Moreover, the uncertain duration of operations and ICU stay, as well as the unforeseeable emergency cases, is a complicating factor in surgical scheduling.

Faced with similar challenges regarding availability of services, peak demands, and capacity utilization, industry has developed methods to deal with these problems. One of these methods is to explicit create and use master schedules, which are repetitively used, for subsequent production steps. In such a master schedule, repetitive jobs are scheduled leading to improved utilization of scarce resources and coordination in the supply chain [4,5].

Based on this experience, the aim of this study is to assess, by means of computational experiments, the benefit of a comprehensive cyclic case schedule for a university hospital and a virtual hospital with a different case mix.

2. Materials and methods

Erasmus MC's main OR department consists of 16 ORs. Planning data have been electronically collected since 1994. From this extensive database, we obtained data on frequencies and durations of specific surgical cases and on the standard deviation of duration of all surgical cases. We also obtained data on related length of stay in the ICU if applicable. Erasmus MC has a tertiary referral case mix. Its mean utilization rate was 85.5%.

The Erasmus MC case mix differed from case mixes of community hospitals. Therefore, besides the experiments using Erasmus MC data, experiments are performed using a case mix of a virtual hospital. The procedure for constructing a data set of the virtual hospital was as follows. The surgical cases from the Erasmus MC data set were put in descending order of frequency. We then selected surgical cases from the ordered list until half of the total surgery volume of the Erasmus MC was accounted for. Subsequently, the frequency was doubled to obtain a case mix with the same volume as the case mix of the Erasmus MC. Table 1 depicts the data for Erasmus MC and the virtual hospital.

Table 1 Descriptive characteristics of the data sets of Erasmus MC and the virtual hospital

	Erasmus MC	Virtual hospital
Data		
Total annual case volume (h)	18549	18861
Mean case duration (min)	142	104
Standard deviation (min)	36	30
Mean no. of required ICU beds per day	6	5
Assumptions		
Mean OR utilization (%)	85.5	85.5
Accepted risk on overtime (%)	31	31

We used the block planning method that is currently used in the Erasmus MC as starting point for the analysis [2,6]. In the Erasmus MC's block planning method, months in advance blocks are assigned to surgical department that subsequently plan their patients in the available OR time according to strict rules. One of these rules is to plan reserved OR time for emergency patients and the reduction of overtime [7-10]. The amount reserved for the latter depends upon a chosen probability, which is in the Erasmus MC set at 31%.

The use of an master surgical schedule (MSS) implies the following 3 stages in the case scheduling process. First, the length of a cycle period is determined, and an MSS is constructed for that period. Thereafter, surgical departments will assign actual patients to the surgical case types incorporated in the MSS. Patients who require a surgical case that is not incorporated may be scheduled in one of the OR blocks that are kept free. At this stage, all patients are assigned to a specific day, for which the clinicians can make the appointments with the patient for surgery. Stage 3 finally provides for the admission of emergency cases and possible replanning of elective cases.

The focus of this article is on the first stage, that is, determining the optional cycle period and the construction of an MSS for such a period. The choice for a particular cycle period was of importance because it determined the number of surgical cases that could be incorporated in the schedule. A longer cycle period lead to a larger set of surgical cases that is on average performed at least once. Given the cycle length and, consequently, the number of case types per cycle, the optimal case schedule was constructed using mathematical optimization techniques. Its ultimate aim was 2-fold: optimizing the use of OR time and minimizing the peak demands of required ICU beds for elective surgical patients [8]. We applied the method of Van Oostrum et al [8], by which first the OR utilization is maximized by reducing the unused OR capacity, and subsequently the ICU bed requirements are leveled. Maximization of OR capacity was accomplished by generating sets of case types that fitted in one OR, such a set is referred to as Operating Room Day Schedule (ORDS). A column-generation approach generated and selected an optimal set of ORDSs [11].

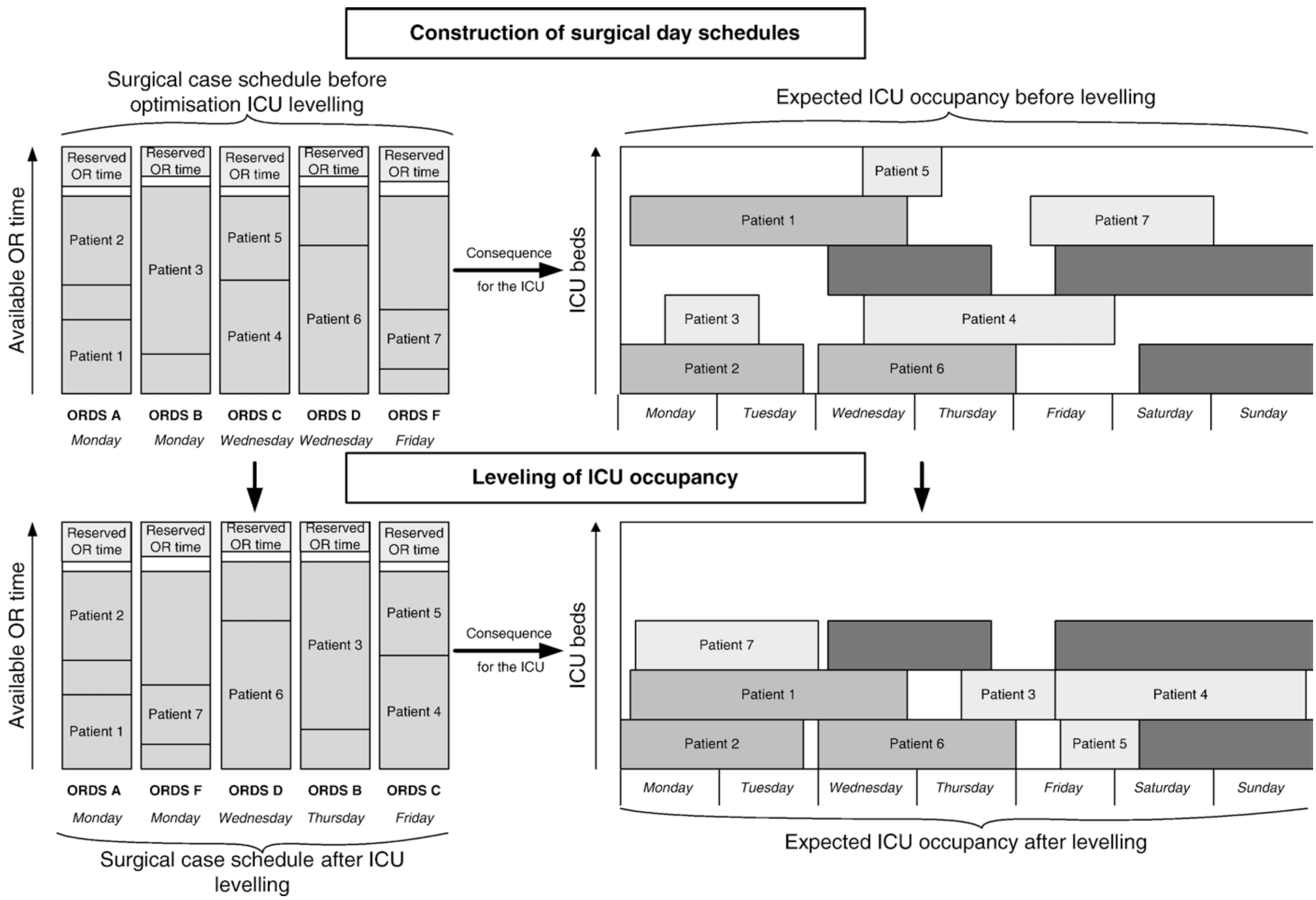

Fig. 1 Overview methodology for construction of an MSS.

Such an approach starts with an initial set of ORDSs that is generated by a longest processing time heuristic [12]. A longest processing time heuristics applied to surgical case scheduling orders at first all case types based on their expected duration. Then, the first case in line is selected and scheduled in an empty ORDS, followed by the next ones in line unless the sum of durations exceeds the available OR time of the ORDS under consideration. Upon this moment, a new ORDS is created, and the heuristic continues adding surgical cases until the capacity limit is exceeded. After all case types are scheduled this way, an initial set of ORDSs is created, which covers all case types to be scheduled in the MSS.

Subsequently, the unused time (slack) in the ORDSs is calculated, and applying linear programming (LP) techniques, a new ORDS is constructed, which may reduce the total capacity needed. This ORDS is added to the available set of ORDSs. A selection of ORDS is made using LP techniques, which covers all-surgical case types; and again, the slack in the all ORDS is calculated [8]. Using the renewed slack calculation, a new ORDS that may reduce the required OR capacity is constructed and added to the existing set of ORDS. These steps are repeated until no ORDS can be constructed, which possibly benefit the amount of required OR capacity.

Hence, each ORDS consists of case type that causes a certain bed requirement profile. To reduce peak ICU peak demands, the selected ORDSs were assigned to a specific OR and particular day during the cycle. Base on an LP formulation of this problem [8], all possible combinations of assignment of ORDS to a specific OR and a particular day were considered using computer modeling. The ICU bed demands of the resulting case schedule were calculated based on the ICU requirements of surgical cases performed in the previous cycles and surgical cases performed in current cycle. For this purpose, we used the mean ICU length of stay for each case type. See Fig. 1 for an example of how an MSS might be constructed. The computer-modeling package

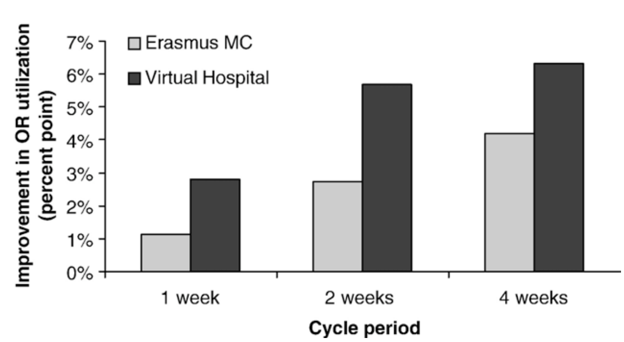

Fig. 2 Operating room utilization for both hospitals and various cycle periods.

AIMMS (Paragon decision technology B.V., Haarlem, the Netherlands) was used to construct the MSS for both Erasmus MC and the virtual hospital.

Any surgical case that was not incorporated in an MSS was scheduled following the current Erasmus MC scheduling method, resulting in similar performance measures. The value of different MSSs was assessed by 2 outcome measures: the increase in OR utilization and the leveling of the number of ICU beds occupied by elective surgical patients. For both Erasmus MC and the virtual hospital, cycle periods of 1, 2, and 4 weeks were examined.

3. Results

Use of an MSS can improve OR utilization considerably by up to 6.3% point. Simultaneously, the ICU workload from such an MSS can be optimal leveled, resulting in less surgery cancellation and fewer ICU refusals. The length of a single MSS cycle has a strong influence on the obtainable improvement of OR capacity. In addition, the virtual hospital potentially has benefits more than the Erasmus MC does (Fig. 2).

Fig. 3 presents for the Erasmus MC a comparison of the ICU demand when it used an MSS, with a 2-week cycle period, compared to a situation when no MSS is used. Comparable results hold for other cycle periods of the Erasmus MC and the virtual hospital.

Data analysis yields that the cycle period is important for the proportion of surgical cases incorporated in the MSS as well as that of total related ICU workload (Table 2). The MSSs for Erasmus MC incorporated fewer cases than that for the virtual hospital. In addition, shorter cycle periods resulted in smaller proportions.

4. Discussion

The aim of this study was to determine the benefits of an MSS in terms of improved OR utilization and leveling of

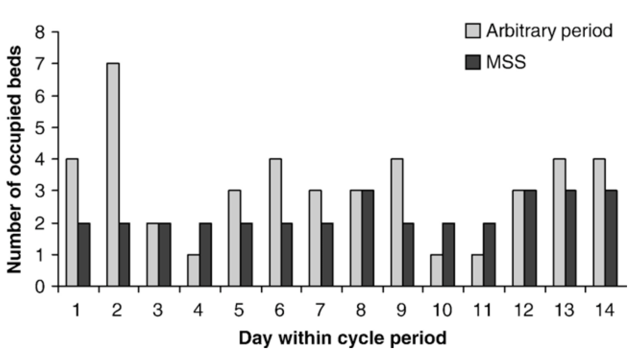

Fig. 3 Number of occupied ICU beds by patients for which a surgical case was incorporated in an MSS with a cycle period of 2 weeks compared with an arbitrary chosen 2-week period (June 3, 2004, until June 16, 2004) in the Erasmus MC. Note that approximately 70% of the ICU demand of elective surgical patients is incorporated in the MSS (see Table 2).

Table 2 Description of the influence of length of the cycle period on the proportion of surgical cases incorporated in an MSS and on the proportion of the ICU demand of surgical patients

	Cycle period			
	1 y	4 wk	2 wk	1 wk
Proportion of surgical cases incorporated in an MSS (%)				
Erasmus MC	100	53	42	27
Virtual Hospital	100	80	75	62
Proportion of the ICU demand of surgical patients determined by an MSS (%)				
Erasmus MC	100	45	38	17
Virtual Hospital	100	74	69	68

ICU workload. Computational experiments showed for the Erasmus MC and a virtual hospital that a cyclic case schedule is indeed able to reduce peak demands on the ICU while at the same time increasing OR utilization. Apparently, the seemingly conflicting goals of efficiency and access to hospital services can be optimized simultaneously.

Existing literature on surgical case and ICU scheduling is mostly concerned with scheduling of add-on cases, emergency cases, and allocation of OR and ICU time to departments [13-15]. Only a few authors have investigated the use of cyclic surgical case scheduling approaches [16-18]. None of them, however, proposes a case scheduling method that actually schedules individual surgical case types, accounts for uncertain case durations, and levels the associated workload on ICUs. Hence, MSSs described in this article enriches the available literature and available case scheduling methods.

We assumed that the Erasmus MC block planning method was used. This implies that OR time is reserved to deal with emergencies and to lower the risk on overtime. Hence, 100% utilization is not obtainable. A higher accepted risk on overtime results in a higher norm utilization. In combination with the assumption that surgical cases that were not incorporated in an MSS were scheduled following the current Erasmus MC practice, the potential improvement may therefore differ for other hospitals depending on their choice to accept overtime and their current OR scheduling practice.

Like the durations of surgical cases, length of stay on the ICU and surgical wards may be highly unpredictable, particularly in a tertiary referral environment. A system that guarantees no cancellation of surgical cases needs a considerable amount of reserve capacity [10]. Unless this capacity is available, leveling of bed requirements by taking into account mean length of stay reduces the probability of peak demands. This helps to reduce the number of case cancellation. An adequate registration system is therefore indispensable to predict surgical duration and bed usage. Note that leveling of ICU bed requirements only concerns the proportion of surgical cases incorporated in an MSS and that therefore the obtained benefits strongly depend on the proportion of ICU bed requirements incorporated in an MSS. The remaining part of the ICU bed requirements might be leveled according to other principles such as the method of Kim and Horowitz [19].

When a single surgical department schedules its patients independently from other departments, the result is a suboptimal schedule in terms of ICU demands and OR utilization. A more flexible hospital organization and cooperation between different surgical departments may further improve the surgical schedules in terms of OR utilization. An MSS as described in this article offers the opportunity to integrate such flexibility in the care pathway and hence optimize or utilization and level ICU demand.

The use of ORs by various surgical departments on the same day has large organizational implications such as the requirements for specialized equipment, multiemployable personnel in all ORs, and possibly longer changeover times. Moreover, the daily activities of clinicians are influenced by the unpredictable durations of surgical cases of other surgical departments. Operating room utilization is higher when surgical cases of multiple surgical departments can be scheduled in the same OR, on the same day [9]. A hospital should make a trade-off between OR utilization and the flexibility to schedule surgical cases from multiple specialties in the same OR on the same day. Nevertheless, a cyclic planning approach that includes the use of an MSS is also applicable to a single surgical department.

Clinicians are responsible for the patient scheduling, which is a requirement for implementation. In addition, most clinicians already have a repetitive schedule. The same type of patients is every week operated on the same day. An MSS offers the opportunity to optimize OR utilization and level ICU bed requirement for all clinicians together. Therefore, it functions as communication tool between planners, clinicians, and other services within hospitals for which an MSS structures for example material coordination. Consequently, the week-to-week case scheduling requires less effort, and the administrative burden on medical staff is lowered because an MSS provides a substantial part of the final surgical schedule.

Our findings show that the proposed cyclic OR planning policy results in a leveled outflow of patients toward the ICU. Although in this study we have focused on reduction of surgical case cancellation because of ICU bed shortages, leveling of other resource requirements might be beneficial for other aspects of a hospital's organization, for example, required intraoperative navigation systems, numbers of fluoroscopy equipment, availability of beds on the ward, and fluctuations in the required number of postoperative computed tomography scans.

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