



Trade-offs in operating room planning for electives and emergencies: A review



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ARTICLE INFO

Article history:

Received 21 November 2014

Accepted 19 May 2015

Available online 3 July 2015

Keywords:

Operating room
Emergencies
Planning
Scheduling
Literature review

ABSTRACT

The planning of the operating rooms (ORs) is a difficult process due to the different stakeholders involved. The real complexity, however, results from various sources of variability. This variability cannot be ignored since it greatly influences the trade-offs between the hospital costs and the patient waiting times. As a result, a need for policies guiding the OR manager in handling the trade-offs arises. Therefore, researchers have investigated different possibilities to incorporate non-elective patients in the schedule with the goal of maximizing both patient- and hospital-related measures. This paper reviews the literature on OR planning where both elective and non-elective patient categories are involved. It shows the various policies, the differences and similarities in the research settings and the resulting outcomes, whether they are beneficial or not. We find that the dedicated and the flexible policy are mostly pursued, but the setting and the assumptions of the reviewed papers vary widely. Decisions on both operational policies as well as on capacity are required to assure timely access and efficiency, which are the two main drivers for the problem at hand. Furthermore, the policy choice impacts the number of schedule disruptions and the OR utilization. However, results on the overtime and the patient waiting time are partly contradicting. The review shows that some policies have already received considerable attention, but the question of which policies are most appropriate is not yet fully answered. Neither has the full spectrum of policies been explored. The paper also addresses the remaining challenges for research in this field.

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1. Introduction: Sources of variability

Ideally, the healthcare sector would be able to deliver the highest quality of care at the lowest cost by providing the right resources at the right time to the right patient. Unfortunately, the life of healthcare providers (and patients) is made difficult due to all kinds of variability. Examples of events inducing variability in the complete surgical process include:

- Late arrivals of patients or no-shows
- Late arrivals of medical records
- Late or early arrival of medical staff
- Delay in support services
- Inaccurate reservation of resources
- Setup, clean up or change over time variability
- Illness of patient or medical staff
- Acute onset of abnormal medical conditions (e.g., infections)

- Surgery duration variability
- Duration variability of all upstream and downstream activities (length of stay)
- Arrival of emergency patients

Many of these aspects determine whether or not the operating rooms (ORs) will run out of time or whether patients need to be cancelled. Moreover, the OR schedule influences the workload of several other departments in the hospital, such as the intensive care unit (ICU), the wards, the laboratories and the Emergency Department (ED). For instance, the daily variability in the elective OR caseload is the main cause of ED diversion to other hospitals [1] or of the variability in the downstream resources [2]. Finally, emergencies are another cause of variability and need to be taken into account in order to guarantee sufficient capacity.

Litvak et al. [3] introduced the terms 'natural' variability and 'artificial' variability, which were later adopted by other authors. The former consists of variability due to the different types of diseases, each with a varying degree of illness (clinical variability), due to the unpredictable arrival of patients (flow variability) and due to the differences in the professional abilities (professional variability). This natural variability drives up the cost of care, can hardly be

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<http://dx.doi.org/10.1016/j.orhc.2015.05.005>

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avoided and thus must be optimally managed. The 'artificial' variability is both non-random and non-predictable [1]. Here, many causes can be possible including patient preferences or practices of the provider. One example is the day-to-day variation in the elective scheduled caseload, which is introduced into the system by the scheduling process. This variation covers the largest part of the occupancy variation from the OR [3,4]. Artificial variability disorganizes the system since an efficient organization, where supply is nicely matched with demand, is made impossible. Haraden and Resar [2] even report that the effect of artificial variability caused by personal preferences and beliefs of the surgeons far exceeds the natural variability.

From the stochastic aspects listed before, the literature focuses mainly on the three last ones: surgery duration uncertainty, uncertainty in the length of stay (LOS) (or bed availability) and arrival of emergency patients.

First, surgery duration variability can be countered by having good estimates (e.g., [5]) or by for instance planning the expected duration increased by an amount of slack, in order to avoid overtime with a certain probability (e.g., [6]). Huschka et al. [7] show for an outpatient setting that this considerably affects patient waiting time without greatly affecting patient throughput or OR utilization. Secondly, the LOS variability can be partly reduced by having a master surgery schedule (MSS) that takes the LOS into account (e.g., [8]). As this paper focuses on the OR, the LOS will be further excluded from the analysis of performance measures. Thirdly, the arrival variability can be tackled in different ways, which is the main focus of this review. It is important that this arrival variability both holds for electives as well as non-electives.

Clearly, these stochastic processes cause a need for policies to guide the decisions of the OR managers on how to manage the planning of the ORs. Unfortunately, the literature on how to include non-elective patients is scarce. Cardoen et al. [9] confirm that only limited research is being done on non-elective patient 'scheduling'. Since non-electives are intrinsically difficult to plan, most literature on operating room planning only reports scheduling practices for electives [10]. Moreover, only 29% of the reviewed papers by Guerriero and Guido [10] consider stochastic aspects. Most of these papers use tailored heuristics to overcome the computational challenges (e.g., column generation-based heuristic). Despite the research on this topic, the need for better access times for emergencies remains pressing today [11].

2. Tackling the trade-offs

The difficulty in scheduling patients in general is the trade-off between cost and efficiency on the one hand and the quality of medical care and patient's preferences on the other hand. The unpredictable nature of emergencies and the fact that they should be served on short notice creates an extra trade-off between allocating operating theater resources to non-elective patients or to elective patients. More specifically, since electives can be scheduled in advance, hospitals pursue a high efficiency level reflected in high utilization rates, acceptable patient waiting times and short turnover times. However, for emergencies, responsiveness or quick access is required. Ferrand et al. [12] discuss this trade-off in healthcare and other domains.

In order to deal with this well-known trade-off, three policies for handling emergencies are pursued: the flexible, the dedicated and the hybrid policy. In the flexible policy, there is no separate OR reserved for non-electives and several rules and scheduling strategies are used in order to manage the access for the two patient categories. Both advanced scheduling strategies as well as operational strategies for on the day of surgery must be defined. In the dedicated policy, one or more ORs are dedicated to a specific patient type in order to separate the flows of the patient categories.

The hybrid policy is a combination of both in which for instance some capacity is reserved for non-electives, but other ORs are also accessible by non-electives. The different policies, illustrated in Fig. 1, are further discussed in more detail.

3. Organization of the review

We searched the database Web of Knowledge for relevant manuscripts, written in English and appearing between 1990 and 2014 in the areas of operations research management science and health care sciences services. Search phrases included: emergent surgery planning/scheduling, emergency theater, semi-urgent surgery planning, urgent surgery planning/scheduling, non-elective patient scheduling, emergency operating room, dedicated operating room capacity and operating room capacity emergency. Furthermore, other relevant papers were selected based on reference list checking and the criteria explained below.

This review focuses on the OR literature that directly impacts or explicitly considers non-elective surgeries. More specifically, this means that the non-elective patient category should be taken into account in the operational or tactical decision making. It includes both research on tactical allocations (capacity) as well as on operational patient scheduling. Mainly papers that use (technical) operations research techniques (mathematical modeling, simulation) are discussed. Papers reporting on data-analysis are included if the focus is on a comparison between (the implementation of) different policies. Other managerial papers are not classified, but are mentioned when they provide specific insights. Other techniques such as workflow management and business process re-engineering (e.g., [13]) are not included. Papers that deal exclusively with non-electives in the up- and downstream resources such as the ED and the ICU (e.g., [14]) are not included in the classifications. Finally, disaster management is also considered to fall outside the scope of this review.

Only a few papers make an enhanced comparison between a flexible and a dedicated policy (e.g., [15–18]). In Section 4, they are classified under both policies, while in Sections 5 and 6 they are classified only in the section where they are assessed to be most relevant. When a paper discusses more than one policy, it is classified under the policy that receives most attention in the paper.

In the patient scheduling literature, there is a lack of consistent designation of patient categories. The following terms are all used to describe patients who cannot be scheduled well in advance: emergent, urgent, add-on, work-in and semi-urgent. We will further use the term non-electives throughout this review to address this patient group.

The rest of the review is structured as follows. Section 4 provides an overview of the characteristics of the building blocks that are used in the reviewed papers. Section 5 discusses the literature on the flexible policy and Sections 6 and 7 treat its dedicated and hybrid counterpart respectively. Challenges for researchers and conclusions are addressed in the final two sections.

4. Characteristics of the building blocks

When comparing papers, the researched setting and the corresponding assumptions are important. This section describes these building blocks of the literature on non-electives in the ORs. The first two subsections discuss the policies in relation to respectively the scope of the research combined with the size of the case hospital, and the time window of the dataset combined with the decision level. The third subsection looks at the modeling assumptions. Since categorization and prioritization are important aspects for non-elective 'scheduling', the fifth subsection clarifies them, followed by a review on the ratio of non-electives to elective patients. Finally, the type of analysis and the applied solution techniques are summarized.

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