Applied Methods in Prioritization of Patients in Surgery Waiting Lists

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Abstract

Surgical cases constitute one of the most important activities in hospitals and it is a fact that publicly funded health systems have waiting lists for scheduled surgeries. Since there is no systematic mathematical modeling of assessing the relative priority of patients on surgery waiting lists, it is difficult to manage waiting lists to ensure that patients with the highest urgency are served first. Most systems currently prioritize patients for general surgery by time-honoured methods based on “First come, First served”, clinical Urgency-Related Groups (URGs), Maximum Time Before Treatment (MTBT), and Prioritization Scoring Algorithm (PSA). Such systems are highly subjective and inadequate to assess and compare urgency and case-mix of patients. Despite the importance of this issue, there is little research in this area. Therefore, this study focuses on existing methods for prioritizing surgical patients on waiting lists by reviewing related articles until 2014 published in international journals. The intention of this review is to give an indication of current trends in researches and proposing some directions for future researches. We conclude that research into prioritizing surgery waiting lists based on mathematical modeling is still in its infancy stages, and that further progress in this field would benefit in decreasing waiting lists, mortality rate and improving the quality of healthcare.

Keywords
Surgical patients, Surgery waiting list, Prioritization, Quality of healthcare.

1. Introduction

Access to treatment based on right priority (by considering equity, urgency and benefit) is one of major issues within healthcare organizations. This access is defined as “the degree to which individuals are inhibited or facilitated in their ability to gain entry to and to receive care and services from the health care system” according to US national library of medicine [2]. Access is influenced by many factors, but from the patient’s perspective, perhaps the most important is how long they must wait for the care they need. Waiting times influence by doctors and hospitals, and the length of time patients wait for treatment is not always shows the severity of their conditions [20]. All waits are not equal. Some waits may clinically be necessary while some others may be only an inconvenience. Long waits and delay in treatment can have negative consequences on patients, it may lead to significant risks of complications or death and result in a poorer quality of care. Berthelot and Sanmartin in their research showed that long waits for care can contribute to declines in health status and poorer outcomes of care, and can impact the health care system overall. Based on their report, Canadians inform that such waits lead to increased worry, anxiety, stress and pain [1].

From all medical, social and economic point of view, surgical processes are one of the most important activities in hospitals. Then, adequate decision-making for prioritization, planning and scheduling (Operating Rooms) ORs is important, as it may greatly impact the quality of care and the costs of hospital.[3] Much research indicates that an ineffective schedule is one of the main factors contributing to the inefficiency. Therefore, adequate decision-making for prioritization, planning and scheduling ORs is of vital importance, as it may greatly impact the quality and the costs of the surgical process [5]. OR planning and scheduling is usually decomposed into three
phases (see Figure1). These phases are: Session Planning Problem (SPP), Master Surgical Schedule (MSS) and Elective Case Scheduling (ECS) [3, 4, 5].

![Figure 1: OR planning and scheduling decisions [3]](image)

However, these three phases are necessary but for an accurate planning and scheduling they are not enough. There is an important phase of prioritization which should be considered (See Figure 2 for proposed OR planning and scheduling decision). Surgical patients’ prioritization affect surgery scheduling. Consideration of patient priority results in significant differences in surgery schedules from the schedule that ignores the patient priority [8]. Despite the importance of this issue, there is little research in this area. Therefore, this study focuses on current and early methods for prioritizing surgical patients on waiting lists. The intention of this review is to give an indication of current trends in researches and proposing some directions for future researches which will be the starting point to develop tools for better prioritizing surgical patients. The rest of the paper is organized as follows. In Section 2, we briefly explain about waiting list and waiting time. Section 3 explains waiting list and prioritization and review related literature. Section 4 discusses and illustrates used methods and gaps for prioritization of surgical patients. Conclusion and Future work are provided in Section 5.

![Figure 2: Proposed OR planning and scheduling decisions](image)

2. Waiting lists and waiting times

Wait-lists and wait-times are important issues to many healthcare organizations. Long waiting lists are among the most heard complaints especially for operating rooms, and some studies aimed at decreasing these waiting times. Many governments around the world monitor their waiting list numbers and waiting times for surgery in order to measure the success or failure of their particular health system in meeting the needs of their constituents [9]. In the UK, several papers [11, 12] report public concern about long-waiting times for treatment. Waiting times and overcrowding in the USA have also increased as reported in [12, 13]. The story is the same in Canada with excessive waiting times leading to adverse outcomes for patients in some instances [14]. International comparisons on wait times for (elective) surgeries suggest that Canadian peoples do experience relatively long waits.
Waiting lists and waiting times are conceptualized in various ways [15], including the following:

- Measures of access to health care services,
- Mechanisms to allocate and ration health care services,
- Indicators of unmet need and/or inadequate resources within the health care system,
- A waiting list is a queue of patients who are deemed to need a health service that is in short supply relative to demand [20].

In effect, two waiting lists are often operating: one to see the specialist who controls access to the desired service and another to receive the service once medical need has been verified. This second list is generally what is referred to by the unqualified term “waiting list” [15]. Waiting time is defined by a complex interaction of factors, including hospital capacity, number of surgeons and the number of patients on waiting lists and the number of emergencies arising and etc. Long waiting times for many medical procedures effect directly on patients health and quality of care. The Fraser Institute reported that patients were waiting an ever-increasing length of time for a wide range of medical services, including specialist consultations, diagnostic services, and surgery, and that actual waits often exceeded physician-defined “clinically reasonable” waits. For many medical procedures, patients face significant risks of complications or death when treatment is delayed. These risks are much higher for patients in surgery waiting lists. Reducing the length of waiting times and eliminating inequities in access to wait-listed services are a prime concern of hospitals. Waiting list anxiety and discourse is a chronic condition in Canada, and at least some patients awaiting care, and their families, do genuinely suffer. But despite this issue’s prominence, there is insufficient information on waiting lists and times, and there are few valid tools to aid in determining patients’ priority for medical treatment [15].

3. Waiting lists and prioritization

Elective surgery waiting lists apply to patients who are waiting longer than 24 hours for a surgical procedure, either for same-day or a multi-day stay [14]. The waiting time for each patient is measured from when a procedure is registered onto the elective surgery waiting list to the day that the procedure takes place. Patients waiting can lead to loss of opportunity for care, which may result in higher health care costs due to additional treatments and lower quality of life. Patient whose surgery is delayed may end up being lost to the system. That may occur in the form of having the surgery done in another hospital or country, giving up, becoming emergency patient if his/her health deteriorates, or death [17]. Then, prioritization of patients for surgery is fast becoming a clinical reality and it is an international phenomenon. Patient priority represents medical and/or social needs, and it indicates the relative position of the patient in a waiting queue. The most prevalent prioritization method is classifying patients into urgency groups, and each of the urgency groups is given a recommended timing for treatment. It is, however, unclear which generic criteria should determine the patient priority. In general, medical condition, disability and social factors are considered in addition to specific criteria related to disease specific outcomes [8].

The current prioritization system most commonly, a patient’s name is placed on an elective surgery waiting list after a lengthy process of referral, specialist assessment and investigation. Patients placed on a waiting list have been assessed to have a clinical need for surgery and are expected to benefit from that surgery. Despite this, the concepts of clinical “need” and “benefit” are ill defined. Currently, patients are classified into nationally agreed-upon clinical urgency categories that take into account the likelihood of deterioration and are aligned with recommended waiting times for surgery. The problem is that assignment of urgency categories applies a basic form of prioritization, it is an informal and relatively insensitive process that does not assure transparency and equity of access to available services, and does not take into account the numerous factors that can contribute to a patient’s urgency for surgery. The lack of specific guidelines to help surgeons make decisions about patients’ need for surgery is a shortcoming of the current system that may compromise patients’ equity of access and clinical outcomes [16].
3.1 Early Prioritisation Formulae
Since late 1960s several prioritisation formulae were developed with the aim of reducing waiting times and prioritizing patients for equal access to treatment. Some of these systems encountered technical difficulties [18]. For the holistic view, we gathered all early formulas (by considering Mullen’s study) in the following table (Table 1) [18]:

<table>
<thead>
<tr>
<th>Description</th>
<th>Proposed Prioritization formula</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Luckman J. (1969) [37],</td>
<td>$P = S^d T^e$</td>
<td>where $P$= priority score; $S$=social factor (1–3); $D$=disability factor (1–3); $T$=time on waiting list (weeks); $a$ and $b$ are constants.</td>
</tr>
<tr>
<td>Fordyce and Phillips (1970) [38],</td>
<td>$A1 = (aS)(bD)(T)e^a$</td>
<td>$S$=social factor; $D$=disability factor (1–5); $w$=urgency of condition (0–5); $T$=time on waiting list (weeks); $a$, $b$, and $c$ are constants.</td>
</tr>
<tr>
<td>Phoenix (1972) [39]</td>
<td>$P = DTw^e$</td>
<td>Luckman J. (1969) proposed formula simplified to this one.</td>
</tr>
<tr>
<td>Eltringham and Clare (1973) [40],</td>
<td>$P = 806(1 - e^{-I})$</td>
<td>$P$=patient’s priority score; $k$=urgency; $T$=time on waiting list.</td>
</tr>
<tr>
<td>Clare (1973) [41]</td>
<td>$P = e^{c \sqrt{T}}$</td>
<td>$P$=priority score; $L$=expected length of stay; $c$=constant; $w$=urgency or deterioration factor; $T$=time on waiting list.</td>
</tr>
<tr>
<td>Culier and Cullis (1976) [42]</td>
<td>$P = e^{c(T + 28)}$</td>
<td>$P$=total priority score; $S_i$=score for $i$th clinical factor</td>
</tr>
<tr>
<td>Langhman &amp; Thorogood (1996) [43],</td>
<td>$P = \sum_{i=1}^{3} A_i \cdot \sum_{j=1}^{5} B_j$</td>
<td>$P$=total priority score; $A_i$=score on $i$th element of the clinical severity criterion ($i=1$ suffering (physical or mental) (values 0, 3, 5 or 7); $i=2$ disability (1, 3, 5 or 7); $i=3$ clinical cost of delay (1, 3 or 6); $B_j$=score on $j$th element of the capacity to benefit criterion ($j=1$ degree of improvement anticipated; $j=2$ likelihood of improvement).</td>
</tr>
<tr>
<td>Soljak, (1997) [44], Hadorn&amp; Holmes, (1997)[45]</td>
<td>$P = \sum_{i=1}^{3} S_i$</td>
<td>$P$=total priority score; $S_i$=score for $i$th clinical factor</td>
</tr>
<tr>
<td>Dennett and Parry (1998) [46],</td>
<td>$P = E \cdot \sum_{i=1}^{5} S_i$</td>
<td>$E$=(100 – age)/30 if age &gt; 70</td>
</tr>
<tr>
<td>Seddon et al. (1999) [47],</td>
<td>$P = \sum_{i=1}^{n} S_i^2 \cdot w_i + \left( \frac{5i}{m - 1} \right)^2$</td>
<td>$t$=time already waited and $m$=waiting time of the longest wait.</td>
</tr>
</tbody>
</table>

The priority score in all the early systems, was intended to be used to specify order of surgery [18]. Whereas scoring systems are not precise enough for prioritization of patients. Besides, these systems didn’t consider various perspectives, risks and criteria. Also interrelationships between these criteria were ignored.

3.2 Non-formulae prioritisation approaches
Naylor et al. [19] in 1990s prioritized patients in their study. They described a different approach on a scoring system for coronary revascularisation. A priority code has been given to each patient at the time of referral and they have been prioritized based on an Urgency Rating Scale (URS). The URS was organized by a panel of cardiologists and cardiac surgeons. It contained seven different levels ranging from emergency (that requires immediate operation) to markedly delayed (which has a 3–6 months waiting time). Prioritization based on other considerations has also been proposed for situations where risk of death is low [20]. An application of real time systems to surgical waiting lists was described by Davis and Johnson [21]. They developed a computerized model in two versions, for elective conditions, and for critical conditions to get a “Patient’s Eligibility Quotient”(PEQ) starting from “Patient’s Initial Quotient”(PIQ). For elective version, patient morbidity factors; social or career effects; and disease
progression were three dimensions and in the time critical conditions version, dimensions were: rate of progress of disease; ability to influence outcome; and degree of distress. Using a basically multiplicative model scores on these three dimensions were combined in order to produce a PIQ. PEQ determines position on the waiting list, to produce it the PIQ was multiplied by waited time [18]. Recently, Domènech et al. developed a prioritization framework for general (elective) surgery by considering Clinical-functional impairment, Expected benefit and social role as main dimensions [43].

3.3 Integrated prioritization and scheduling approaches

In the previous decade, MacCormick et al. [22] and Mullen [18] provided an extensive survey of prioritizing patients in a waiting list. Patrick et al. [23] in their model attempts to schedule patients to fixed scheduling slots of a diagnostic resource within the maximum recommended waiting time that is given to each priority. Min et al. [8] in their paper studied the effects of patient priority on the surgery schedule, namely the decision of the number of patients selected from a waiting list. They showed that the consideration of patient priority results in significant differences in surgery schedules from the schedule that ignores the patient priority. Ozkarahan et al. [24] use an integer goal programming approach to select which patients to schedule and in which ORs to schedule them on a single day. Testi et al [5] study a problem with a similar scope using discrete event simulation to judge the quality of different scheduling policies. Other research that focuses on selecting which patients and which ORs does so over the course a longer planning horizon (typically one week) (Ogulata and Erol [25], Lamiri et al. [26, 6], Min and Yih [8]. Each of these papers relies on a multi-stage model to address the separate decisions of choosing which patients and then assigning them to specific ORs on specific days. Ogulata and Erol [25] use a hierarchical mathematical programming approach, while Lamiri et al. [26] use a column generation algorithm. Both Lamiri et al. [6] and Min and Yih [8] use two-stage stochastic programming techniques.

Most of the research that focuses on assigning patients to ORs and sequencing the cases within ORs focuses on the single day problem. The two-stage nature of the problem again necessitates sophisticated heuristics or multi-stage solution procedures. Jebali et al. [27] solve a series of integer programs. Pham and Klinkert [7] model the problem as a job shop scheduling problem and find solutions using mixed integer linear programming. Hans et al. [28] use off-line bin-packing heuristics to create robust schedules using planned slack, and their work is the exception in that it schedules cases over the course of a week rather than a single day. Other research is more targeted in its focus. Guinet and Chaabane [29] model the assignment of patients to operating rooms (without regard to sequencing) as a generalized assignment problem and use a primal-dual algorithm to find high quality solutions. Denton et al. [30] assign cases to operating rooms using a stochastic programming model to incorporate uncertain case durations. Figure 3 shows used methods for incorporation of patient priority in a scheduling problem. According to this figure, Queuing theory, Simulation, Linear Programming and Stochastic Dynamic Programming are the most used methods respectively. In the next parts we discuss more about shortcomings of literature and give some directions for future work.

![Figure 3: Used methods in integrated approaches](image-url)
4. Discussion
Waiting lists for treatment especially for surgery are a topical issue in many hospitals. Because patients often experience long waiting times with a negative impacts on their health and quality of life. Since the 1960s, research has shifted in the field of prioritization with the aim of ensuring prompt access for patients most in need [18]. Study and research have been put forward from different viewpoints to better understand behaviour, causes and function of waiting lists, as well as to define theories that explain their persistence and design policies to reduce their length. The development of prioritization instruments has been the strategy followed by some countries like New Zealand, Canada and the United Kingdom among others to manage waiting lists according to patient’s needs and expected benefit from surgery [39]. Since the development of these instruments are costly and lengthy, they generally have been focused on specific diseases.

Based on Victorian Healthcare Association (VHA), the current surgery waiting list process is ineffective as a measure of service access, unreliable as a benchmarking or prioritization tool, and popularly misused as a measure of how well a health service is performing. Most systems currently prioritize patients by time-honoured methods based on “First come, First served”, clinical Urgency-Related Groups (URGs), Maximum Time Before Treatment (MTBT), Prioritization Scoring Algorithm (PSA) and etc. Such broad classification systems are highly subjective and inadequate to assess and compare urgency and case-mix of patients on waiting lists. Problems with the current system is that the assignment of urgency categories applies a basic form of prioritisation. It is an informal and relatively insensitive process that does not assure transparency, benefit and equity of access to available services, and does not take into account the numerous factors that can contribute to a patient’s urgency for surgery. The lack of specific guidelines to help surgeons make decisions about patients’ need for surgery is a shortcoming of the current system that may compromise patients’ equity of access and clinical outcomes [16].

Our literature review reveals that, although, several models were proposed, they were all based on different principles without great international agreement. Besides, it indicates that different tools were developed for surgery either based on implicit semi quantitative or explicit quantitative criteria, however none of these tools were good enough to consider benefit, urgency and equity simultaneously for achieving more structured prioritization. The bar chart in Figure 4 shows the distribution of the reviewed articles in three categories (Non formulae-based prioritization, Formulae-based prioritization and Integrated with scheduling) from 1969 to 2014. It indicates that, between 1969 till 2000 formulae-based prioritization (earlier methods) was developed and between 1989 and 2008, the studies in both formulae and non-formulae-based prioritization and integrated domain grew sharply. In summary, to the best of our knowledge the research that addresses exactly patient prioritization problem (other than earlier methods which had technical difficulties and shortcomings) were not found, and since 2009 to date only the incorporation of patient priority in a scheduling problem was conducted which didn’t provide any solution particularly for prioritization problem.

Figure 4: Distribution of the reviewed articles.
5. Conclusion and Future research

In this paper, we reviewed manuscripts on prioritization tools for surgical patients reported to date. We noticed that most of the research is directed towards the planning and scheduling of patients. While there are not much attention paid to prioritization of patients for surgery. We believe that prioritization as a first step of OR planning and scheduling will have an influential effect in achieving good results. In summary, good prioritization methods will help to improve the efficiency and equity (fairness of the prioritization system of hospitals), so that patients' access to appropriate and effective medical services will be prioritized on the basis of need and potential to benefit. To this end, for the future researches, prioritizing surgery waiting lists based on mathematical modeling applied in other industries such as Multi criteria Decision Making approaches, Operational Research methods, Risk management tools and etc. will help in development of valid, reliable, practical and clinically transparent measures of surgical patients’ priority and further progress in this field would benefit in decreasing waiting lists, mortality rate and improving the quality of healthcare.

Acknowledgements

This research was partially financed by grants [OPG 0293307 and OPG 0118062] from the Canadian Natural Sciences and Engineering Research Council (NSERC). This support is gratefully acknowledged.

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