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A new dynamic integrated framework for surgical patients' prioritization considering risks and uncertainties

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ABSTRACT

This study reviews current patients' prioritization systems and presents an innovative integrated three-step decisional framework in an attempt to overcome their limitations. In its first step, the proposed framework encompasses fuzzy logic, analytic hierarchy process (AHP) to formalize stakeholders' goals and objectives. In the second step, the assessments made on each patient's condition are integrated by data envelopment analysis (DEA) and compared among them by a min–max regret approach (MRA) to obtain a primary prioritization of patients. The third step uses the delay ratio, the risk criteria score, and a profile matrix to introduce dynamic aspects related to the evolution of patients' condition and changes in the patient's list to the prioritization process. This three-step framework not only considers the surgery team members' opinions but also considers the patient's opinions in the decision-making process. The new framework has been implemented in the Orthopedic Surgery Ward, Shohada University Hospital, Iran, showing very promising results and advantages.

1. Introduction

After patients are referred for surgery, their situations are evaluated. If surgical patients have a non-life-threatening condition, they will be admitted, usually on a first come, first served basis. If, however, a surgical patient's condition is potentially life-threatening, the patient will be entered onto a priority waiting list [1]. Higher priority patients will be treated ahead of those with a lower priority, regardless of when were added to the list, while the same priority patients are ranked based on the arrival order [1]. Patients' prioritization on waiting lists and their access to treatment based on various factors are two of the major issues in public systems as patients often suffer from consequences due to long waiting times [2–6]. During the last years, elective surgery rates have increased in most of Western countries [7], and waiting times have become a serious health policy issue in OECD countries [8]. The Fraser Institute [9] reported that the total waiting time in Canada in 2015 was 95% longer than in 1993.

According to Russell et al. [10], there is an increasing imbalance between the demand and availability of access to elective surgery for less urgent elective procedures. This imbalance causes long waiting times, and consequently, some patients wait longer than what is clinically recommended [10]. In many medical procedures, these long waiting times directly affect the patients' health and quality of care. Reports regarding the harms related to long wait times are numerous; these harms include poorer medical results from care, an increased risk of adverse events [9], discomfort and anxiety [11,12]. The Fraser Institute estimated that 44,273 Canadian women have lost their lives between 1993 and 2009 as a result of lengthy delays in receiving care [13]. In their study, Prentice and Pizer [14] showed that long wait times result in negative health outcomes such as patients' mortality. Day [15] highlighted that "for some diseases delayed treatment can cause reduction in effectiveness of treatment, and often transforms an acute and potentially reversible illness or injury into a chronic, irreversible condition that involves permanent disability." Although this imbalance between demand and availability of access for elective surgeries is mostly caused by a shortage of human resources (surgeons and nurses), waiting lists management and appropriate patients' prioritization can play an important role in diminishing undesirable outcomes, such as patients' injury or mortality. Several researchers [16–20,10,7] stressed the need for an interdisciplinary and collaborative research to explore systematic and precise prioritization frameworks.

The specific research questions addressed in this paper are as follows: (a) Can patients prioritization methods help healthcare organizations improve both the effectiveness and the fairness in access to health care services? And if so, b) how can a prioritization method be developed so that it takes into account the problems and challenges

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faced by decision makers in real healthcare contexts? To answer those questions, we have reviewed the scientific literature related to patients' prioritization and we have identified the main drawbacks of current prioritization approaches. Based on that analysis, we have proposed a general and integrated framework able to prioritize patients in complex dynamic systems, taking into account multiple decisional criteria, considering both medical staff and patients' opinions, risks, uncertainties, and incomplete information. The framework encompasses a three-step decision system. The first step includes a multicriteria decision-making tool to structure and define the stakeholders' goals and objectives. In the second step, each patient is evaluated with respect to each criterion by a group of experts to obtain an individual score. Individuals' scores are treated together to produce an initial rank. The third step accounts for the dynamic evolution of patients, allowing to periodically update the rank of patients and provides a profile matrix to help decision makers graphically trade off risks and delay in treatment.

The remainder of the paper is organized as follows. Section 2 presents a short review of classic prioritization tools and their shortcomings. The proposed framework for the surgical patients' prioritization as well as the tools selected to accomplish each step is explained in Section 3. Sections 4 and 5 focus on a real case observed at the Orthopedic Surgery ward, Shohada University Hospital in Tabriz, Iran. Section 4 illustrates the use of the framework, while Section 5 compares the proposed framework to the current prioritization method. Section 6 provides a conclusion and suggests future research works.

2. Literature review and drawbacks observed in current practices

According to Hadorn [21], patients' prioritization is a very complex decision-making process. In general, patients' priority can be defined by the position of a patient on the waiting list, patient-specific characteristics, or the contribution to an objective function or to a combination of factors [22]. Some authors [23–28,21,17] proposed various prioritization scoring systems to assist health professionals in making better decisions when determining which patients will receive treatment first. A scoring system or points system consists of a method for defining the patients' relative priorities for treatment. A weighted set of criteria is proposed and each patient is assessed with respect to every criterion. The sum of all the values gives a "total score" for each patient, which is used to rank patients between them. Pioneer scoring systems introduced in the 1990s were criticized for being arbitrary and resulting in significant numbers of patients being mistakenly denied treatment (sometimes with fatal consequences). However, similar scoring systems have been proposed and are largely in use in Italy, New Zealand, the United Kingdom, Canada, and other OECD countries. For instance, scoring tools are currently used in Canada in five main clinical areas (i.e., cataract surgery, general surgery procedures, hip and knee replacement, magnetic resonance imaging scanning, children's mental health) [29].

Prioritization formulas were also developed with the aim of reducing waiting times and improving prioritization, [30–32,25] (see Mullen [19] for a complete review of prioritization formulas). Naylor et al. [33] suggested assigning each patient, upon referral, a priority code based on an Urgency Rating Scale (URS). Prioritization based on other considerations has also been proposed for situations where the risk of death is low [21]. In a review on prioritization systems of elective patients, MacCormick et al. [34] thoroughly discussed the different prioritization factors and their weighing. Valente et al. [2] developed a model to prioritize access to elective surgery on the basis of clinical urgency and waiting time. Testi et al. [35] emphasized in their research the importance of using both urgency related groups (URGs) and scoring system for scheduling patients' admissions in an explicit and transparent way.

Patients' prioritization also concerns other types of medical activities such as organ transplants [36–41,20], traumas [42,43], and it is also relevant to intensive care units' activities [44]. Despite all these efforts, some important points are still overlooked and some major shortcomings in current prioritization systems need to be improved [16–19,10]. Among them, special attention should be devoted to the following aspects. First, the majority of current prioritization tools cannot ensure that the ranking results are robust enough to face the inherent uncertainty involved in healthcare decision-making processes [29]. Second, most of the current prioritization tools overlook the associated risks that could threaten patients' health during the waiting time. Third, despite the increasing number of professionals working as a team during patients' treatments, the prioritization decision rests mostly on the surgeon's opinion. This may introduce a bias in the prioritization procedure, and result in the dissatisfaction of other medical staff that could be avoid or mitigated by using group decision-making methods. Fourth, current prioritization procedures are static (patients' conditions are evaluated upon their addition to the list). However, waiting lists are dynamic (patients are added and removed from to list) and their condition evolve over time. Lastly, there is no systematic and comprehensive framework for surgical patients' prioritization on waiting list. This study seeks to address the above-mentioned drawbacks in current prioritization systems by proposing a comprehensive dynamic risk-based framework for patients' prioritization.

3. Proposed Methodology

In this section, the proposed framework is explained and the tools used in each of the steps are discussed and explained. The tools' application will be thoroughly presented in the Case Study section.

The first step establishes relative importance among the selected criteria and risks, structuring them according to the stakeholders' objectives. In the proposed framework, a fuzzy multicriteria decision-making (MCDM) technique is proposed to determine the weights of different criteria and risks [45] by considering several health professionals' opinions. It should be noted that in order to handle the associated uncertainties in mapping the decision maker's qualitative and quantitative judgments, fuzzy logic is used to accept semantic evaluations or assessments. This process is done at the deployment of the system and, eventually, at large intervals in order to adjust the prioritization system to the institution evolution and changes (every 6 months or yearly).

The second step focuses on patients' assessments and is done at the arrival of the patient. The patient assessment is performed for every criterion and risk situation selected in step 1. It is worth mentioning that although a surgeon often does patients' assessments, our framework proposes a group decision making approach (GDM) to integrate the evaluations of several experts on each criterion and risk to produce a patient's score. Then a min–max regret approach is used to produce a ranking of the patients.

The third step deals with the dynamics and evolving aspects of the waiting list system. This step is frequently performed (once a week or every two weeks) according to the rate of addition and removal of patients to the list. It uses two dynamic factors, namely, the delay ratio and risk criteria score, aimed at capturing the evolution of patients to update their position on the list if required. Last, a risk delay matrix is used to visually support decision making.

3.1. Step 1: identifying and formalizing the prioritization criteria and risks

The identification and description of prioritization factors (criteria and risks) is one of the most important steps in the prioritization procedure. Among all the stakeholders (including surgeons and other medical staff, but also representatives of patients), semi-structured discussions should be held in order to identify related criteria and risks, gain a clear and shared understanding of their meaning, and reach a consensus on the final selected criteria and risks to consider using group decision-making techniques, such as the TRIAGE or the Delphi techniques. Once a set of criteria and risks is agreed upon, their relative importance, as well as the potential interactions among them, needs to be stated. To this end, the analytic hierarchy process (AHP), an MCDM technique