A novel multi-criteria decision-making approach for prioritization of elective surgeries through formulation of “weighted MeNTS scoring system”

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ABSTRACT

Background: Publicly funded healthcare system has long non-manageable elective surgery waiting lists due to the non-existence of systematic mathematical modelling that can assess the relative priority of patients on elective surgery waiting lists thus denying the provision of surgical support to the patients with higher urgency. Mostly the patients of general surgery are entertain with highly subjective “time-honoured” methods that are inadequate to measure and compare the urgency of surgical procedure.

Objective: A methodology of assigning priorities to patients on elective surgery waiting lists has been presented in this paper using weighted criteria objectives. The objectives have been chosen and assigned weights based on hospital conditions, and in consultation with the surgeons in hospital in Pakistan.

Methods: The proposed methodology presents two working contributions; first, a scoring mechanism based on MeNTS scoring system with weighted criterion that objectively translate the condition of patient prior to the surgical procedure; and second, a patient prioritization methodology to select patients for surgeries according to the corresponding scores. Detailed simulation results from actual patient data have been presented to evaluate the effectiveness of the proposed methodology, and its applicability and ease of use has been tested in real-time by surgeons while providing consultations to their patients.

Results: The proposed methodology outperforms the traditional “first-come-first-serve” methodology as there was a 30% reduction in average waiting time in elective surgery waiting lists (from 4.246 to 2.956 days) with 103 (90%) of patients being entertained before or within the unprioritized surgeries time span, with 94 patients having surgery within 1 day of being on waiting list (an increase of 47 patients). Moreover, transparency and equity were also found in the adaptation of this strategy to prioritize the elective surgery patients.

Conclusions: Prioritizing patients on elective surgery waiting lists is an important concern in surgical field. In most of the methodologies presented in earlier research, prioritization of patients for surgery is carried out subjectively. This study shows that the proposed technique has the potential to decrease the waiting times for patients on elective surgery waiting lists, as well as be presented as an objective methodology for preparing the elective surgery waiting lists to increase the transparency in waiting list.

1. Introduction

Surgery is the branch of medicine concerns with the disease and trauma that require physical manipulation of a body structure to diagnose, prevent, and/or cure a disease. The act of performing surgery is also known as a surgical procedure or operation [1]. Surgeries can be emergent or elective, while emergent surgeries are performed immediately, elective surgeries are postponed for a specific time and are performed when patient becomes due for procedure as ascertained by the examining surgeon during clinical examination of the patient [2].

Effective planning of the flow of surgical procedures in the operating theatres (OTs) through surgical scheduling is critical to managing the patient loads for medical service providers. This planning is normally divided into three stages: planning of the case-mix, master surgical scheduling, and prioritization of patients in Elective Surgery Waiting Lists [3]. Elective surgery waiting lists are established to organize the
uncertain flow of patients and to smooth out the workload of healthcare providers. However, unacceptable long waiting times on elective surgery waiting lists result due to ever increasing gap between demand and supply [4]. Long elective surgery waiting lists is one of the most prevalent issues in countries where the health services systems are publicly funded [5]. Long waiting time result in dissatisfaction customers as it triggers anxiety, frustration, distress, anger, and uncertainty [4, 6] as result in adverse outcomes for patients [6] and resulantly present a risk to the care quality. Studies [6] identified that prolonged waiting results in worsening of symptoms, quality of life, prolonged leave of absence from work resulting in loss of income, and even death of patients.

Prioritization is a process that rank the patients for surgical procedures based on a given set of criteria. Usually the criteria are defined subjectively due to which it becomes challenging to compare the needs of patients [7]. It has received significant attention by researchers in recent years to optimize it. However, practically assessing the priority of the patients based on explicit criteria is complex and inconsistent procedure. Since this prioritization is not based on a single decision, it becomes a complex multi-criteria decision-making (MCDM) process [5]. Researches [9, 10] indicated that no prioritization method is being applied in the public hospitals in Pakistan and surgery sequencing is based on professional judgment of the surgeons. Similar findings have been reported by other researchers [11, 12, 13, 14]. It was highlighted that after the clinical examination of the patient, the examining surgeon determines the health status of the patient and based on their professional judgment and hypothetical rational thinking, presented pathological reports and the severity of the patient’s disease, the patient is placed at appropriate position in the elective surgery waiting list. Such arrangement is subjective in nature, and such decisions face criticism of lacking transparency, delaying the surgical treatment in time, denial of much needed treatment to those deserving it the most, judgmental errors during assessment, emotional & ethical burden on surgeons, enhanced workload, and mismanagement of the hospital resources [11]. Such concerns can be mitigated if a surgical decision-support tool with a well-defined scoring system that caters the extent of disease, criticality of the surgical procedure, and health of patient is used to guide the surgeons [8, 12].

A scoring system computes the patient-mix and uses the resultant score to determine the outcome as a measure of patient’s health quality. Such a system is prepared by integrating easily measurable patient data into a predefined algorithm that eventually provides a single score. This score is used to predict the illness status of the patient, the progress of the treatment, and even the response toward clinical intervention, and provides a common ground for communication amongst a range of health care professionals [15].

Authors [8] considered the scoring systems as good decision-making tools as these have been used by surgeons and clinicians since 1990s. However, these authors further highlighted that these scoring systems were also criticized for being error-prone primarily as these were random in nature and resulted in erroneous denial of treatment to substantial numbers of patients even with few fatal consequences. Most of the established scoring systems are used as risk stratification tools. A “risk stratification tool” is a scoring system or model that predicts the post-surgery mortality or morbidity of the patients in emergency/trauma surgery. These tools include ASA-NSQIP, CCI, ESAS, PESAS, POSSUM, SMS, SAS, SRS, SORT, etc. [16]. Scoring systems for surgery prioritization have been developed by countries including New Zealand, Italy, Germany, and Norway, etc., suiting their own particular environment [8]. The literature reviewed indicates that in Pakistan, the research on operation theatre (OT) management and surgical decision-making is non-existence. Studies have indicated that elective surgery waiting lists in public hospitals are informally prepared and executed on “first-come-first-serve” basis without the application of any other prioritization method [9].

In order to facilitate the surgeons in such surgical decision-making and provide triage and prioritization of patients, Prachand et al. [11] developed Medically Necessary, Time-Sensitive (MeNTS) scoring system to manage resources during the COVID-19 pandemic that integrated twenty-one factors related to the surgical procedure (7 factors), disease (6 factors) and the patient (8 factors). Values from 1 to 5 were assigned by the surgeon against each factor based on measurable objectives and observed clinical probabilities during the examination. The cumulative MeNTS score (minimum 21 and maximum 105 points) is the result of sum of all the points recorded for all the factors. MeNTS scoring system has also been modified and applied in the field of paediatrics [17] and orthopaedics [18]. Several other Specialty-specific tools and scoring systems have been suggested to guide surgical decision-makers for prioritizing the surgeries during the COVID-19 pandemic, such as Johns Hopkins prioritisation system for gynaecologic [19], spine surgery urgency score [20], and pediatric surgical wait priority score [21] for prioritizing surgeries in hospitals with limited resources.

A major shortcoming in MeNTS scoring system is that it uses same weights for all factors or criterion irrespective of their importance, which may result in “false sense of objectivity”, and same has been observed in modified MeNTS as well as other scoring systems [17, 18, 19, 20, 21]. Majority of MCDM methods that rely on weighted aggregators, face the problem in determining the weights of the criteria as weights contribute towards selection of preferences. The weighting methods can be divided into three categories: objective, subjective and combınative or hybrid weighting methods. Irrespective of the method used, the ultimate goal of weighing the criterion is to give objectivity to the decision-making method [22].

A weighted scoring system is presented as a way to allow objective prioritization of the elective surgery waiting lists. Prioritization based on weighted scoring can utilize numerical scoring to rank patients, thereby making it more dependable and reliable, and at the same time, ensuring transparency and equity. A new weighted factor scoring system is being proposed based on a modified MeNTS scoring system with weighted factors for objective prioritization of patients in elective surgery waiting lists. A major objective of this study was to ensure that the numerical method techniques used do not introduce any additional delays. This tool was utilized in actual hospital settings, and the results have been presented in this publication, indicating that it does not incorporate additional delays in the waiting list, while at the same time, it provides an objective methodology for prioritization and improves the average waiting time of patient on elective surgery waiting lists. It may also act as a foundation for introducing further tools that are suitable for prioritizing the patients on elective surgery waiting lists.

MeNTS scoring system is a good tool that can be used for prioritization of elective surgery waiting lists after assessment of patient, the related disease and procedure to be performed; still, the clinical complexities warrant a system that can distinguish and weigh the factors or criteria that gauge the health of the patient in a wholesome manner. Prachand et al. [11], Slidell et al. [17] and Prabhakar et al. [18] made similar observations while working on the MeNTS scoring system and its variants. Waiting list prioritization systems have been developed for individual specialties like Johns Hopkins gynaecologic prioritisation system [19], spine surgery urgency score [20], and pediatric surgical wait priority score [21], however, all these system also lack the weighting of the criteria. In this paper, we have proposed a prioritization approach that improves the average waiting time of patients on elective surgery waiting lists without incorporating additional delays and providing an objective methodology for prioritization of waiting lists using the weight factors or criteria to gauge the actual health status of patients. The actual deployment of the proposed methodology needs to be studied in greater detail, and validated further, but details of the simulation that has been carried out so far as a part of validating this methodology has also been presented in this paper, with some very encouraging results.

The rest of the paper is organised as follows. The next section provides the details of the proposed methodology. The results of study are presented, followed by an analysis of these results. Conclusion and avenues of possible future work/research are provided in the last section.
2. Methodology

In this study, MeNTS scoring system has been modified considering the resource utilisation, procedural intricacies, and patient’s health status, etc. The proposed system is based on 17 weighted factors that have been distributed into procedural factors (7 factors), the disease factors (5 factors) and patient factors (5 factors). Fleiss’ kappa, a measure for assessing the inter-rater reliability, was calculated, with four different surgeons (raters) examining 10 patients (targets) and scored them using modified weighted scoring system. Simulated surgeries were performed to check the efficacy of the prioritization.

2.1. Factors excluded, modified, and added

Taking lead from previous research mentioned above, a modified weighted scoring system based on weighted criteria or factors has been introduced in this study as a result of TRIAGE, i.e., “Technique for Research of Information by Animation of a Group of Experts” activity [23] within the panel of eight experienced general surgeons (average experience 23.3 (SD 1.2) years) for its applicability in Pakistan. Related criteria that can characterize the hierarchy of decisions were identified and validated. The modified scoring system had 17 instead of 21 factors (one factor was added and five factors were removed) proposed in the previous research [18], in the same three groups. Within the disease group, the “pain & discomfort” factor (in three grades) was added. Following the logic given by Prabhakar et al. [18] during the formulation of orthopaedic MeNTS scoring system, the panel also removed the non-operative treatment option from the original list for being limited and non-functional from the disease group, along with the removal of “influenza-like illness (ILI) symptoms”, and “exposure to known COVID-19 positive persons within a 14-day period” from patient group, since the surgery of such patient is otherwise postponed till they are free of such symptoms. Since the “age” factor from patient group was not considered to be influencing the surgery urgency, it was also removed. Like in the original work, values from 1 to 5 were assigned to each factor based on measurable objectives and observed clinical probabilities. Subsequently, each of the 17 factors is adjusted according to the assigned weight.

2.2. Information collection

Out-patient department and surgery record of one year (2020) was obtained from the hospital. To check the efficacy of the proposed system, data of meeting the criteria was recorded for a period of four weeks using non-probability convenience sampling method. 114 adult patients were clinically examined (full history, physical examination, and review of ancillary test findings) in surgical out-patient department (OPD) by qualified surgeons from 14 September – 8 October 2021. The data was entered immediately after the clinical examination on the handheld tablets running especially designed application with modified patient health scoring system. Demographic data of the patient included the age, gender, and medical history. The results of ancillary tests were also examined.

2.3. Assessment of weights to factors

The assessment of weights to the factors was calculated by asking the panel of surgeons to weigh each of the 17 factors according to the relevance and importance on the scale of 1–10, one being most relevant/important. Weights of each factor were calculated using linear sum normalization technique-benefit attributes [24]; if \( a_{i,n} \) be the relevant score (between 1 to 10) given by the surgeon \( n = \{ n \in Z \mid 1 \leq n \leq 8 \} \) to the factors or criteria \( i = \{ i \in Z \mid 1 \leq i \leq 17 \} \).

\[
w_i = \frac{1}{W} \sum_{n=1}^{8} a_{i,n} \tag{1}
\]

The cumulative health score \( S_p \) for a patient ‘\( p \)’ is calculated using following equation in which \( s_i \) is individual factor score as evaluated by surgeon, \( s = \{ s \in Z \mid 1 \leq s \leq 5 \} \), and \( w_i \) is the assigned weight of corresponding factor (Table 1):

\[
S_p = \sum_{i=1}^{17} s_i w_i \tag{2}
\]

The resultant cumulative weighted score ranges between 1.0 to 5.0, with urgent cases having the lower scores. It signifies that the patient needs the surgical procedure on priority and delay will result in a negative effect on well-being of the patients.

2.4. Simulated unprioritized and Prioritized Surgical Waiting Lists

The ‘Unprioritized Surgical Waiting List’ is based on ‘first-come-first-serve’ basis. In said technique, waiting list is prepared chronologically as per their arrival, that is, sequentially by entering the name of patient who arrive earlier before the patients who arrive later. Surgical procedures are then performed on the patients according to the prepared waiting list [25]. ‘Prioritized Surgical Waiting List’ is prepared a day prior to surgical day by sorting the patients within the waiting list based on their cumulative health score in such a manner that patients with lower score or higher priority are placed earlier than patients with higher score or lower priority. Both lists were prepared using computer simulations.

2.5. Average wait time on surgical waiting list

It is defined as the average number of days a patient remains on the waiting list before undergoing surgical procedure. It is an important quantitative measure that can be used to evaluate the waiting list performance [12].

After examination, if a patient ‘\( p \)’ is placed on the waiting list at time (\( t_p \)), then at the time of surgery (\( t_s \)), the average wait time (\( t_{avw} \)) in the waiting list having ‘\( n \)’ number of patients is calculated by following equation:

\[
a_{avw} = \frac{1}{n} \sum_{p=1}^{n} (t_s - t_p) \tag{4}
\]

In both unprioritized and prioritized waiting lists, time (\( t_s \)) remains the same; however, before and after the prioritization, the time of surgery (\( t_p \)) will be different thus affecting \( a_{avw} \)

2.6. Considerations

The adult male and female patients with ages of 15 years & above were included as candidates for the elective surgery. The patients who refused surgery, pregnant women, patients with malignancy/pre-malignancy, and those requiring day surgeries/minor OT were excluded from the study. Another assumption that was made was that all the patients scheduled for the surgery are available and willing for surgery. It was also assumed that the OT staff, the equipment, and any other resources needed (gasses, ICU, PACU and hospital beds) are available and average daily surgeries will be performed as per historical data. Majority of the patients on existing elective surgery waiting lists were not reachable and hence could not be called in the hospital for re-evaluation. Hence, prioritized waiting list based on collection of fresh data was only considered for simulation purposes and no surgical procedure was performed against it, since its application would have disturbed the existing waiting list, which the hospital administration did not allow. Simulated daily surgeries were planned on maximum surgery time (30, 60, 120, 180 and 240 min). Total time to perform daily surgeries was...
simulated within maximum allowed OT operational time of 9 h (540 min) per day. Commercial tools were used for statistical analysis [26] and simulations [27].

2.7. Ethical review and verbal consent

Formal approval of “Ethical Review Board, Department of Management Sciences, Sir Syed CASE Institute of Technology, Islamabad, Pakistan” was taken. Moreover, “verbal informed consent” of the patients was taken prior to recording the data.

3. Results

Computer simulation is widely used as operations research (OR) tool in multi-criteria decision-making (MCDM). As the changes to actual waiting list were not possible, the approach given in this paper has been validated through simulation for both unprioritized and prioritized waiting lists. Through these simulations, waiting times of patients for surgery have been analysed. As surgeries are planned on time rather than numbers, a more practical approach was followed in the simulations by considering the total available surgery time of 9 h (per day) instead of total surgeries.

Fleiss’ kappa was calculated to determine if there was an agreement between surgeons (raters) on 10 randomly selected patients (targets) meeting the inclusion/exclusion criteria. The surgeons were also randomly selected from the department of 29 surgeons to score each patient on modified weighted scoring system. Each surgeon clinically examined the eight patients in a separate room to avoid influencing the decision of the other surgeons. After examining the patient, data was immediately recorded. A Fleiss’ kappa rating between 0.81–1.00 is generally considered to be “Almost perfect Agreement” between raters. Results are given in Table 2. Overall Fleiss’ kappa rating showed that there was “Almost perfect Agreement” between the surgeons’ judgement, $\kappa = 0.835$ (95% CI, 0.757 to 0.914, p < 0.0005).

3.1. Simulation results

Fresh data of 114 eligible patients was collected for 12 OPD days (average of 13.68 patients per day). The study cohort consisted of 65 male (57%) and 49 (43%) female patients. They were examined and scored on modified weighted scoring system that ranged from 1.00 to 4.062 with a mean of 2.315 (SD 0.771).

Male mean score was 2.294 (SD 0.785) and female mean score was 2.342 (SD 0.760).

Simulation of unprioritized and prioritized surgeries started with effect from 14 September 2021 on three days per week basis. The unprioritized surgeries culminated after 39 days on 23 October 2021 whereas prioritized surgeries terminated two days earlier on 21 October 2021. After prioritization of waiting list, there was 30.4% reduction in waiting time of patient on surgical waiting list from 20 days to 14 days (two having 20 days wait time, one each with 23 and 30 days wait time). Number count of different waiting times before and after prioritization are given in Table 3. Similarly, Table 4 enlist 11 (9.7%) prioritized surgeries that had more waiting time than in prioritized list.

4. Discussion

Prioritizing patients is an important concern in surgical field especially in publicly funded healthcare systems which are the target of usual criticism for lacking in transparency, delaying the surgical treatment in time, denial of much needed treatment to those deserving it the most.

Table 1. Weights assigned by the eight surgeons to respective factors.

| Serial # | Factors                 | Surgeons (m) | w_j |
|----------|-------------------------|--------------|-----|
| 1.       | OR Time                 | 6            | 5   | 0.047 |
| 2.       | Estimated length of stay| 4            | 7   | 0.023 |
| 3.       | Post-Op ICU need        | 10           | 10  | 0.070 |
| 4.       | Estimated blood loss    | 10           | 10  | 0.072 |
| 5.       | Surgical team size      | 6            | 7   | 0.048 |
| 6.       | Intubation needed to perform procedure (probability) | 10 | 9 | 0.069 |
| 7.       | Surgical Site           | 6            | 4   | 0.043 |
| 8.       | Impact of delay in DISEASE outcome (2 weeks) | 10 | 10 | 0.070 |
| 9.       | Impact of delay in SURGICAL difficulty/risk (2 weeks) | 10 | 10 | 0.072 |
| 10.      | Impact of delay in DISEASE outcome (6 weeks) | 10 | 10 | 0.070 |
| 11.      | Impact of delay in SURGICAL difficulty/risk (6 weeks) | 10 | 10 | 0.072 |
| 12.      | Pain & Discomfort       | 6            | 5   | 0.040 |
| 13.      | Lung disease (asthma, COPD, CF) | 10 | 9 | 0.072 |
| 14.      | Obstructive Sleep Apnoea| 5            | 6   | 0.043 |
| 15.      | CV disease (HTN, CHF, CAD) | 9 | 9 | 0.067 |
| 16.      | Diabetes                | 8            | 7   | 0.059 |
| 17.      | Immunocompromised       | 9            | 8   | 0.064 |
| Total    |                         |              |     | 1.000 |

Table 2. Score by three surgeons for ten patients to check Inter-rater reliability.

| Patient | Surgeon 1 | Surgeon 2 | Surgeon 3 | Surgeon 4 |
|---------|-----------|-----------|-----------|-----------|
| P1      | 2.110     | 2.110     | 2.110     | 2.110     |
| P2      | 1.568     | 1.568     | 1.568     | 1.568     |
| P3      | 2.322     | 2.322     | 2.322     | 2.322     |
| P4      | 1.555     | 1.701     | 1.555     | 1.555     |
| P5      | 1.717     | 1.717     | 1.717     | 1.717     |
| P6      | 2.162     | 2.162     | 2.162     | 2.016     |
| P7      | 2.733     | 2.733     | 2.733     | 2.733     |
| P8      | 3.925     | 3.925     | 3.925     | 3.925     |
| P9      | 1.596     | 1.596     | 1.596     | 1.596     |
| P10     | 2.461     | 2.461     | 2.429     | 2.461     |
judgmental errors during assessment, emotional & ethical burden on surgeons, enhanced workload, and mismanagement of the hospital resources. This study has been carried out to objectively address such issues by proposing a technique that has the potential to provide surgical healthcare to the needed along with decreasing the general and average waiting time for the patients on the waiting list.

Prioritization of Patient is a criteria-based process of ranking referrals in a certain order to ensure fairness in the management of waiting list [7]. This process is different from the traditional “time-honoured” methods that are based either on “first-come-first-served”, “Clinical Urgency-Related Groups” and “Maximum Time Before Treatment” approaches. The principal difference is how the ranking is accomplished. In traditional methods, “first-come-first-served” approach chronologically places the patients on the waiting lists as per their arrival time. “Clinical Urgency-Related Groups” and “Maximum Time Before Treatment”, are triage-based approaches that place the patients in broad categories or groups with pre-determined waiting times. In contrast, the process of prioritization uses explicit criteria to determine the position of the patient in already established waiting list. Research [28] has indicated that in actual practice, assessment of patients’ priority based on explicit criteria is complex and, to a certain level, inconsistent process. After referral to a surgeon, a patient is clinically examined to ascertain the health condition. Based on this evaluation, examining surgeons decide the surgical procedure to be adopted and the priority of performing the selected procedure. Such judgmental surgical decision-making is primarily governed by hypothetic rational thinking, professional judgment and the pathological reports of the patient [9, 10, 14] along with the presented severity of the patient’s disease, mobility, pain, discomfort, and the necessity of the surgical procedure to be performed [11, 12, 13]. Being subjective in nature, such decisions may face criticism of lacking in transparency, delaying the surgical treatment in time, denial of much needed treatment to those deserving it the most, judgmental errors during assessment, emotional & ethical burden on surgeons, enhanced workload, and mismanagement of the hospital resources [11].

Researchers [29, 30] indicated that such methods lack flexibility that resulted in reduced acceptability by surgeons. Study [30] indicated that only 19.5% surgeons agreed that current prioritization methods are effective in prioritizing the patients while 44.8% highlighted that further development is required for effective prioritizing of the patients. Not only the process is informal but also insensitive that does not ensure transparency and fail to consider numerous factors or criterions that can contribute towards patient’s urgency for surgery. Mainly, the absence of certain factors or criterions that can help surgeons to make decisions about patients’ urgency for surgery is an inadequacy of the current prioritization methods that may affect the clinical outcomes. Such concerns can be mitigated if a decision-support tool with a well-defined scoring system that caters the extent of disease, criticality of the surgical procedure, and health of patient is used to guide the surgeons [8, 12].

According to [8], the current prioritization system is subjective in nature and lack the ability to adequately assess the urgency of patients on waiting lists. Being informal and lacking sensitivity, such prioritization may result in transparency concerns as surgeons may relegate patients based on their personal preferences, delay in surgical procedure otherwise required by relegated patients, denial of urgently required care which is thus denied, errors in judging the condition of patient which may also result in delay of much needed procedure, emotional/ethical burden on the surgeons. Moreover, such a system hinders the surgeons to prioritize the patients. Such a system ignores the urgency for surgery and surgeon must place the patient in the queue. On the other hand, if a patient is given an early surgical time, the surgeon is criticised for giving unfair preferential treatment. In such a dilemma, the treating surgeon is always under ethical and emotional stress.

Such concerns can be alleviated if a decision-support tool with a well-defined scoring system that caters to the extent of disease, criticality of the surgical procedure, and health of the patient is used to guide the surgeons [8, 12]. As already highlighted, scoring system computes the patient-mix and uses the resultant score to determine the outcome as a measure of patient’s health quality. Such a system is prepared by integrating easily measurable patient data into a predefined algorithm that eventually provide a single score. This score is used to predict illness status of the patient, progress of the treatment, and even the response toward clinical intervention, and provides a common ground for communication amongst a range of healthcare professionals [15]. The strength of a health scoring system is its ability to convert subjective responses into objective scores as it revolves around the set of factors or criterion. Researchers [7, 8, 31, 32, 33] indicated that once a tool is available to a surgeon that objectively gives a priority score to the patient, it offloads ethical and emotional load from the surgeon by making decisions.

In the literature [8, 12, 34], average waiting time has been considered important measure to evaluate the performance of the waiting list. It was found that there was appreciable reduction of 30.4% (from 4,246 days to 2,956 days) in the average wait time ($a_{\text{ave}}$) when the waiting list is prioritized. The reduction in average wait time ($a_{\text{ave}}$) is primarily due to the prioritization methodology which the established scoring criteria. The weighted factors ranks the patients in need to undergo surgeries in the early timeframe, as compared to the previously used technique that lacked a systematic procedure of prioritizing the patients as the surgeries were being carried out chronologically. 0.

After prioritization of waiting list, there was a 30.4% reduction in average waiting time ($a_{\text{ave}}$) as it decreased from 4,246 days to 2,956 days. It is noted that 90% (103 out of 114) patients underwent the surgeries before or within the unprioritized surgeries time span. Out of these
103 patients, 94 patients were scheduled for surgery within 1 day of being on the waiting list. This increased number from 37 to 94 is due to addition of patients whose un prioritized wait time has been reduced from 3 or more days (wait time of the remaining 9 patients remained the same). This implies that patients in need received the surgical care in early timeframe than getting the treatment if un prioritized list is followed. Analysis of Table 4 indicate that out of remaining 11 surgeries that were delayed beyond the un prioritized schedule, seven were carried out within 15 days (maximum wait time of un prioritized surgeries), however, two were carried out after waiting of 19 days, and one each after waiting of 23 and 30 days. Thus, at the cost of providing early surgical care to patient in need, the maximum wait time of patient on surgical waiting list has increased from 15 days to 30 days after prioritization for four patients (3.5%) only.

Irrespective of the robustness of a scoring system is, reliability of ratings by the clinicians is an important consideration in diagnosis and subsequent examination findings interpretation. The reliability of the scores, usually nominal or ordinal, becomes questionable when various patients are to be examined by various examiners. This consistency issue can be resolved by measuring the inter-rater agreement or reliability. It is a quantitative measure of the magnitude that explains the level of agreement between two or more raters or judges or observers is given by Fleiss’ kappa, κ [35, 36]. In this study, overall Fleiss’ kappa of “Almost perfect Agreement” between the surgeons’ judgement indicates that the diagnosis of the surgeon is precise, i.e., the same finding has been observed by the doctors examining the same patient, and the diagnosis of the surgeons is acceptable [37]. The difference between the surgeons was only found in procedures for three patients in two factors, i.e., “estimated length of stay” and “post-operative ICU need”. It was necessary to find the level of agreement between the surgeons to obviate disparity in diagnosis as it will directly affect the prioritization of the patients.

A few points were considered, but not included in this study. These will be considered in future studies to improve the methodology further. The first one relates to the waiting time of patients. So far, the formulated prioritization does not cater for the patients who are already on the waiting list. Patients with higher health score already on the waiting list will keep on being relegated by incoming patients with lower scores. Secondly, the scoring system must also endorse re-evaluation visits when clinical condition of the patients already on waiting list changes due to ailment and warrants clinical re-evaluation by the surgeon. In such cases, cumulative changes in the health score can be reflected in the waiting list. Third, the data was collected from a single hospital. Although the patients visiting the surgical OPD belong to a vast area, it is recommended that in future studies, data from other hospitals be collected and compiled data be analysed for better results. Such implementation will result in a more reliable scoring system that can provide objective measure in prioritization of the E elective surgery waiting lists SWL.

5. Conclusion and future work

Prioritizing patients on elective surgery waiting lists is an important concern in the surgical field. In most of the methodologies presented in earlier research to address this, the prioritization of the patients for surgery is carried out subjectively. By considering various factors or criteria, a few authors solved the prioritization of patient during the COVID-19 pandemic; however, weighted factors or criteria were not considered. The study presented in this paper proposes a decision support system for the prioritization of the surgical waiting list of patients by modifying MeNTS scoring system and assigned weights to the selected factors that describe the procedure, disease, and patients’ comorbidities, for the first time to any variant of MeNTS scoring system. The validity of the proposed technique has been shown through simulations. The assumptions made on the resources available for decision making (e.g. the resources and time available for surgeries) have been based on existing hospital data. Statistical analysis shows that the criteria chosen for the decision making is also valid, since it indicates that the surgeons chosen as raters are in agreement.

The presented health scoring system reflects a fair clinical judgement that encourages transparency, equity, and certainty. The methodology does not favour age, gender, doctor’s favouritism, or any other biasness which translates this methodology into a robust technique for prioritization of elective surgical waiting list. Although application of the tool has not substantially decreased the overall waiting time, it considerably reduces the average waiting time of the patients on the elective surgery waiting lists by 30%.

In future research the modified scoring system will be used to develop for an elective surgical triage based on biopsychosocial factors or criteria (personal, social, clinical and any other factor deemed relevant) while using the concept of Urgency Related Groups (URGs). This triage system will indicate respective maximum time before treatment (MTBT). Moreover, a methodology will also be developed that can prioritise the elective surgery waiting list with respect to waiting time on surgical wait list and while considering the limitation of scarce resources such as gasses, ICU, PACU and hospital beds, etc. Usage of presented technique will also be studied for prescriptive surgical data science and decision-making using developed scoring system and triage. The results of these extended study will be presented in the future publications.

Declarations

Author contribution statement

Hasan Sikandar Rana: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.
Muhammad Umer: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.
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Data included in article/supp. material/referenced in article.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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