DETERMINING FACTORS ON LENGTH OF STAY FOR COVID-19 PATIENTS

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Abstract - Understanding how the estimates of hospital length of stay (LOS) change over time is critical, as new pharmacological interventions and medical managements become available for COVID-19 patients. The ability to predict LOS will be crucial, as higher length is associated with cost and capacity utilization due to new variants of the virus that causes COVID-19. Understanding and forecasting hospital bed demand, as well as relevant personnel or equipment requirements, provides important evidence for decision-making and emergency planning. This study aims to determine the factors affecting LOS for COVID-19 patients considering the fact that these criteria may have different priorities with respect to the considered objective. According to the results obtained by considering expert evaluations, the most important factors are found to be the shortness of breath, and the need for nasal and high-flow oxygen.

Keywords - Length of Stay, Multi-criteria Decision Making, Relation Analysis Method.

I. INTRODUCTION

The coronavirus disease 2019 (COVID-19) epidemic has adversely affected human life all over the world and has caused a great burden on healthcare systems. Hospitals represent the largest portion of these healthcare expenditures. Inappropriate hospitalizations and long-term stays are among the leading causes of hospital inadequacy. Appropriate decisions to be made on these issues will provide significant advantages by increasing patient satisfaction and reducing costs. Due to variability in procedures and practices, length of stay (LOS) varies between countries, hospitals and settings. However, the goal that is common all over the world is the reduction of LOS. A short stay may reduce the cost of discharge, while an LOS that is too short can increase costs by being associated with adverse health outcomes and higher readmission rates [1]. On the other hand, a long-term LOS not only increases costs but is also associated with adverse events and potential complications [2]. Therefore, the right balance must be struck between ensuring the quality of healthcare and cost savings. Improvements in LOS can increase capacity utilization through beds and staff time.

In the current literature, there are studies focusing on determining the factors related to the decision of LOS. Many issues including age, seriousness of illness, patient to healthcare workers ratio, hospital size, and treatment outcome at discharge, etc. have been taken into account with this purpose [3]. However, it is ignored that these objectives are not of equal importance and cannot be evaluated in the same way. Thus, understanding the complexity of the factors fundamentally underpinning LOS is a prerequisite and of great importance in setting realistic goals. This study aims to determine the weighted criteria that are effective in determining the LOS, which is related to more than one criterion, and to include the relevant stakeholders in this decision. The study shows that multi-criteria decisions are applied in real life to scientifically evaluate the LOS, through the use of the perspectives of multidisciplinary stakeholders (surgeon, patient or patient relatives, hospital management and other healthcare professionals).

The rest of the work is organized as follows: The next section presents the problem-specific evaluation criteria. In the Methodology and Results section, the steps of calculating the weight values together with real data obtained by the evaluations of experts are presented. The last section focuses on the final results and concluding remarks, presenting the future directions.

II. PROBLEM DEFINITION

The aim of this study is to determine the criteria and sub-criteria to be evaluated for LOS, together with their relative importances. Chiam et al. [4] argued that although each week after the onset of pandemic is associated with decreased LOS, due to the new variants of the virus that causes COVID-19, the ability to predict LOS will be crucial. Alharbi et al. [5] mentioned that LOS is also critical for planning purposes for both the COVID-19 and future pandemics considering all factors that influence it, including comorbidities, complications, gender, age, region of residence, and other demographics Guo et al. [6] proposed a regression model, based on variable selection, containing the predictor variables of sex, transfer from another hospital, fever or chest symptoms, bilateral patchy shadowing on CT, pre-existing chronic kidney or liver disease, creatinine level, and indirect bilirubin level. Birhau et al. [7] claimed that the patients presented with shortness of breathing, incident organ failure, increased leukocyte

count, and blood urea nitrogen (BUN) level had significant association with prolonged hospital stay. Wang et al. [8] showed that age and clinical grade were strongly related to LOS. They recommended that more measures be taken to deal with the COVID-19 outbreak in areas with older and more vulnerable populations and in need of primary medical resources.

The conceptual model applied was developed through literature review and consultation with key stakeholders (surgeons and other medical practitioners, nurses and allied professions, patient or patient relatives, hospital management); criteria and sub-criteria are determined in this context. The information obtained from the research was presented to the group whose opinion was consulted, and with the feedback of the participants, the final criteria and sub-criteria of the model, given in Figure 1, emerged.

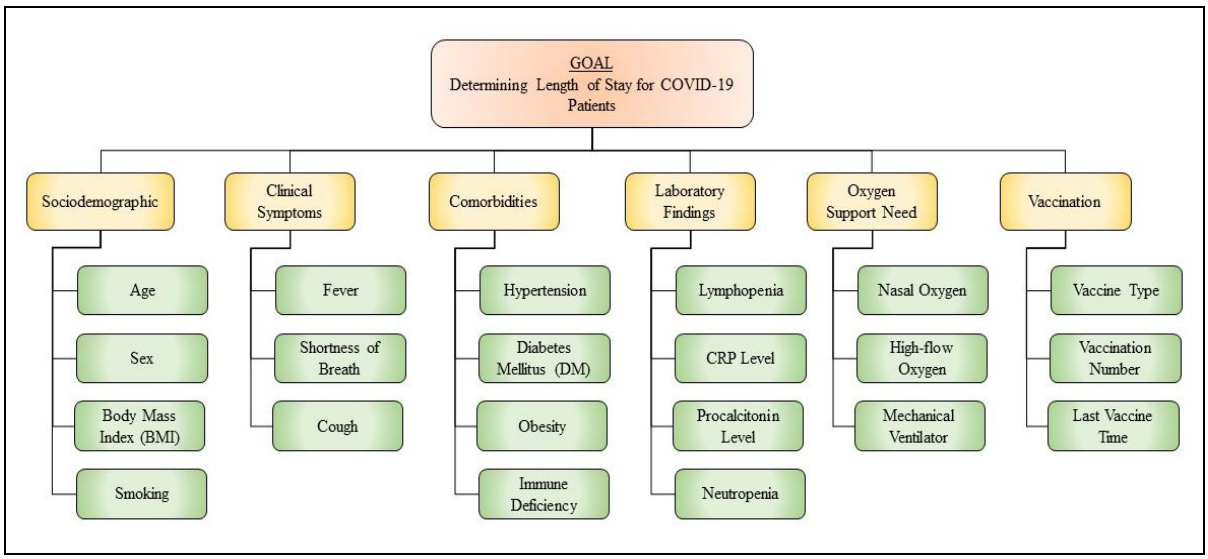


Figure 1. Problem-specific criteria and sub-criteria

If we take a closer look at these criteria and sub-criteria; sociodemographic factors including age, sex, body mass index (BMI) and smoking status constitute the first subset. Romero Starke et al. [9] showed that there is an increased age-related risk of COVID-19 disease severity, admission to ICU, and death. Moriconi et al. [10] claimed that that obesity is associated with extended hospital stay. Regarding smoking status in relation to the COVID-19 rate and severity, there is disagreement between the reported data, in which some studies have reported no association of active smoking with COVID-19 severity, whereas others have reported that active smokers are associated with an increased severity rating and worse outcomes [11]. Clinical symptoms including fever, shortness of breath and cough; which are the most common symptoms on admission. Patients presented with shortness of breath should be estimated to stay longer in the hospital [7]. In most cases, hospital LOS becomes longer for patients with fever than for those without fever on admission [6]. Besides, patients presented with difficulty of breathing, incident organ failure, decreased leukocyte, and blood urea nitrogen level are mostly estimated to stay longer in the hospital [7].

Under the third criteria of comorbidities, we take hypertension, diabetes mellitus (DM), obesity and immune deficiency into account. Moriconi et al. [10] showed that obesity affected by COVID-19 required extended hospitalization and more intensive and prolonged oxygen treatment. Using the definition of count of comorbidities as a proxy for disease severity, Chiam et al. [4] claimed that, every one increase in comorbidity count is associated with an increase in LOS by 2%. In the same study, the most prevalent comorbidity in the COVID 19 population is found to be hypertension (HT). DM and HT are chronic diseases those impair the vascular, and neural systems gradually. Although the direct prolongation of the hospitalization period due to DM and HT could not be demonstrated, it is clear that they will have negative effects on the prognosis of the patients in terms of the severity of the disease and the need for intensive care. Fourth main criterion is laboratory findings, under which we deal with lymphopenia, CRP level, procalcitonin level and neutropenia. Especially, the leukocyte count increment decreases hospital length of stay by 0.95 among COVID-19 patients. Studies showed that leukocytosis is a biomarker of COVID-19 severity clinical stages. This could be indirectly due to increment of leukocyte aggravates the clinical outcome of the patient that results in shortening of length of stay by ending up the stay with death [7]. Sharifpour et al. [12] claimed that in hospitalized COVID-19 patients early thresholds of daily CRP values are observed during hospitalization that may facilitate risk stratification and prognostication. Concerning LOS, despite of a

limited number of studies, lymphopenia identified as a risk factor for the prolonged LOS.

Oxygen support need is the next main criterion that is related to the nasal oxygen, high-flow oxygen and the need for mechanical ventilator. Hypoxia upon presentation, abnormal chest imaging appear to be strong predictors of worse outcomes [13]. Mellado-Artigas et al. [14] showed that the use of high-flow nasal oxygen was associated with increased ventilator-free days and a reduction in the duration of intensive care unit (ICU) stay. The use of high-flow nasal oxygen upon ICU admission in adult patients with COVID-19 related acute hypoxemic respiratory failure may also lead to an increase in ventilator-free days and a reduction in ICU length of stay, when compared to early initiation of invasive mechanical ventilation [14] .

Our last set of criteria is vaccination. Fully vaccinated patients aged 18-79 had a shorter hospital stay and also had lower likelihood of admission to intensive care units. Under this topic we consider vaccine type (M-RNA vs. inactive), vaccination number and the time that passed since the last vaccine. Fully vaccinated patients hospitalized with COVID-19 in Norway have a shorter LOS and lower risk of ICU admission than unvaccinated patients [15].

III. METHODOLOGY AND RESULTS

The method used in the study is the relation analysis method (G1-method) which is a simple and practical method for determining the weights based on the improved Analytical Hierarchy Process (AHP) method.

A.Relation Analysis Method

The specific steps of the G1-method are as follows [16] :

Step 1: Determine the order relationship of the criteria. The decision makers rank the criteria $C_{(1)}, C_{(2)}, \dots, C_{(n-1)}, C_{(n)}$, which is determined as $C_{(1)} \succ C_{(2)} \succ \cdots \succ C_{(n-1)} \succ C_{(n)}$ according to their importance, where $C_{(i)} \succ C_{(j)}$ indicates the importance degree of evaluation criterion $C_{(i)}$ is greater (or not less) than $C_{(j)}$.

Step 2: Determine the importance scale
The relative importance of the evaluation criterion $C_{(j-1)}$ and $C_{(j)}$ is defined by $r_{(j)}$:

$$r_{(j)} = w_{(j-1)}/w_{(j)} \quad (1)$$

where $w_{(j)}$, $w_{(j-1)}$ are the weights of the criteria (j) and $(j-1)$ respectively. However, $w_{(j)}$ and $w_{(j-1)}$ are often unknown, but $r_{(j)}$ can be obtained according to the importance degree of the two criteria by the decision makers. The values are shown in Table 1 [17].

r_j	Description
1.0	C_{j-1} is the same importance as C_j
1.1	Between the same and slightly more important
1.2	C_{j-1} is slightly more important than C_j
1.3	Between slightly more and more important
1.4	C_{j-1} is more important than C_j
1.5	Between more and strongly more important
1.6	C_{j-1} is strongly more important than C_j
1.7	Between strongly more and extremely more important
1.8	C_{j-1} is extremely more important than C_j

Table 1. The value of relative importance.

Step 3: Calculate the subjective weights ω_{sj} of each criterion by Equations (2)-(3)

$$\omega_{sn} = \left[1 + \sum_{i=2}^{n}\left(\prod_{j=1}^{n} r_j\right)\right]^{-1} \quad (2)$$

$$\omega_{sj} = \prod_{k=j+1}^{n} r_k \omega_{sn} \quad (3)$$

B. Determination of Weights of the Criteria

In this study, we focused on determining the importance levels of the criteria affecting the length of stay in COVID-19 patients. After defining the criteria given in Figure 1, the importance levels for each of the six criteria and total of twenty sub-criteria are determined. The comparisons are made by the evaluations of the four experts; 1 intensive care physician, 1 anesthesiologist, 1 infectious disease physician and 1 pain physician. The experts determine the order of the criteria and sub-criteria together with the rationale assignment of r_j values by referencing to Table 1. Related orders and rational assignments for the main criteria are given in Table 2.

	Order	r_2	r_3	r_4	r_5	r_6
1	C2 > C1 > C3 > C6 > C4 > C5	1.8	1.4	1.5	1.2	1.4
2	C5 > C3 > C6 > C1 > C2 > C4	1.4	1.4	1.6	1.2	1.4
3	C5 > C2 > C1 > C3 > C4 > C6	1.6	1.4	1.4	1.6	1.4
4	C5 > C2 > C3 > C1 > C6 > C4	1.6	1.4	1.2	1.4	1.6

Table 2. The orders of experts and rational assignments.

Evaluations with respect to the sub-criteria under each of the six main criteria are collected and analyzed using the same steps. At the end of the proposed methodology, subjective priorities are obtained with respect to the objective of determining the LOS for COVID-19 patients. These priorities are given in Table 3.

	Criteria	Sub-criteria	Weights
C1. Sociodemographic	0,153		
C11. Age		0,415	0,064
C12. Sex		0,159	0,024
C13. Body Mass Index (BMI)		0,287	0,044
C14. Smoking		0,138	0,021
C2. Clinical Symptoms	0,230		
C21. Fever		0,297	0,068
C22. Shortness of Breath		0,490	0,113
C23. Cough		0,212	0,049
C3. Comorbidities	0,166		
C31. Hypertension		0,141	0,023
C32. Diabetes Mellitus (DM)		0,169	0,028
C33. Obesity		0,305	0,051
C34. Immune Deficiency		0,385	0,064
C4. Laboratory Findings	0,070		
C41. Lymphopenia		0,303	0,021
C42. CRP Level		0,260	0,018
C43. Procalcitonin Level		0,204	0,014
C44. Neutropenia		0,233	0,016
C5. Oxygen Support Need	0,277		
C51. Nasal Oxygen		0,328	0,091
C52. High-flow Oxygen		0,252	0,070
C53. Mechanical Ventilator		0,421	0,116
C6. Vaccination	0,104		
C61. Vaccine Type (M-RNA, Inactive)		0,508	0,053
C62. Vaccination Number		0,291	0,030
C63. Last Vaccine Time		0,201	0,021

Table 3. Weights of the sub-criteria.

As can be seen from the Table 3, need of mechanical ventilator has the highest priority, which is immediately followed by shortness of breath. They are followed by the need for nasal and high-flow oxygen, respectively. And the total effect of these four factors constitute almost 40% of the overall observations. Another 40% effect is distributed among the seven criteria; namely fever, immune deficiency, age, vaccine type, obesity, cough and BMI. Remaining ten factors are hardly effective on hospital LOS, as they have a total of 20% priority.

IV. CONCLUSION

In this study, we focused on defining the priorities among the factors affecting length of stay in COVID-19 patients. A number of effective criteria that are important with respect to the considered objective are defined by the help of the literature researches and the information obtained from the experts, and the problem is organized in a hierarchical framework consisting of six main criteria and twenty sub-criteria. Different decision-making methods can be used for future research, and the results can be compared with the results obtained in this paper.

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