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Multi-Factor Triage Algorithm (MUFTA): Quantitative and Qualitative Ethical Factors on Triage Decisions During COVID-19

Shamsuddin Ahmed [1*], Rayan H. Alsisi [2]

[1] *Professor, Department of Industrial Engineering, Faculty of Engineering, Islamic University of Madinah, 42351, Kingdom of Saudi Arabia.*

[2] *Vice Dean for Graduate Studies and Scientific Research, Faculty of Engineering, Islamic University of Madinah, 42351, Kingdom of Saudi Arabia.*

Abstract

Background: This study shows how multiple ethical criteria evaluations result in patient screening and ranking. Furthermore, as Omicron outbreaks increase, hospital emergency departments will become overburdened with critically ill patients. It is a one-of-a-kind global triage algorithm for infectious decreases of COVID-19 and Omicron. The algorithm is qualitative and quantitative, and adaptable to various bio-ethical and social factors. The measurement of the evaluation process eliminates any inconsistencies, which is an advantage of a decision-making algorithm. The proposed algorithm is unique because there are no similar algorithms in the literature that provide triage guidelines based on social ethics, bioethics, and human dignity. *Objective*: It's simple to evaluate a patient's potential benefits when ethical triage judgments are structured and transparent. Furthermore, decisions made primarily based on economic considerations in stressful situations overlook the socioeconomic realities of the underprivileged. This triage algorithm eliminates the need for ad hoc triage evaluations and facilitates criteria for inclusion, such as human dignity. It also takes into account patient comorbidities and social, ethical issues. *Method*: Healthcare professionals use predefined ethical criteria to assign relative rankings among patients based on treatment response and social circumstances. It is a Delphi method for evaluating patient illnesses with the help of medical professionals. For example, the admission to the intensive care unit and providing a ventilator depend entirely on hierarchical multidimensional triage scoring results. This algorithm can evaluate triage scores quickly. It is robust, accurate, and quick in assessment, evaluation, and reevaluation during an emergency. A team of three experts can implement this algorithm. *Result*: The Consistency Scores (CR) show how well clinical and non-clinical ethical criteria may be used to make triage judgments. As a result, all specialists have reported allogeneic reactions in the triage assessment. Furthermore, this system enables decision-makers to identify cognitive biases that may influence their decisions. A Group Consciousness Ratio (GCR) of over 85% indicates that the decision-making process is transparent. Patients with a high level of social dependency, a reasonable probability of recovery, a favorable weighted average comorbidity score, and those who are less fortunate are all considered in the overall triage decision. *Conclusions*: This algorithm differentiates patients who need ICU (Incentive Care Unit) care and do not immediately require critical resources. As a result, patients queue up on a waiting list when the ICU demand spikes due to the increased incidence of COVID-19 infection or its variants. This situation presents a dilemma for the triage policy. Therefore, a national emergency policy requires monetary and technical assistance to expand healthcare facilities. However, the clarity of this triage policymaking is at odds with decision-makers interested in manipulating results. It is challenging to deal with consistency issues in the Delphi process in group decision-making without professional moderators and valid evaluation metrics. Therefore, transparency, consistency, and strong judgment are essential elements of the presented algorithm.

Keywords:

Triage;

Multi-Factor Triage Algorithm (MUFTA);

Social Ethics;

Decision Making;

Covid-19;

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1- Introduction: Ethics Guidelines on COVID-19 Triage

The purpose of triage regulation is to reduce the burden on decision-makers. Triage helps patients allocate critical resources as needed. Transparent triage is essential for making decisions [1]. It should reflect the dignity of the patient and a fair distribution of vital resources and maximize the benefit to society while following the expected values of

* **CONTACT**: dr_shamsuddin_ahmed@yahoo.com

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quality life. According to ethical guidelines, allocating scarce resources provides moral justification for healthcare professionals. Decision-making and patient triage processes should be transparent, comprehensive, evidence-based, and support the appeals method with new evidence or expert opinion [2, 3].

Triage guidelines benefit a patient who shows prospects for long-term survival. Some guidelines emphasize short-term survival as a criterion; others consider a long-term prognosis, reduced life expectancy, age limits, and comorbidities. The preference of patients or their representatives provides an opinion in triage reviews. If the treatment does not offer an advantage for a cure, almost all guidelines justify the end of treatment [4, 5]. A patient who is a health professional gets priority as a front-line defense worker. A complex case may require an alternate assessment and triage decision using a computer algorithm for clinical data, patient information, and ethical considerations. The software should support the characteristics of patients, clinical knowledge, and patient data that are unusual for decisions [6].

Treating critically ill patients during the pandemic is crucial because of the lack of ICU ventilators and medical staff. Due assessment of management of critical care resources and examination of high-risk patients requires due assessment. Many European countries have issued COVID-19 screening guidelines over several years, and many countries, such as Austria, Germany, the United Kingdom, Belgium, etc. In Italy and Switzerland, in crisis and life-threatening conditions, COVID and non-COVID patients can receive treatment according to predefined criteria [7–13]. Ventilation support, ICU admission, and irreplaceable treatment needs are more common in COVID-19 infected patients. Lack of resources complicates the situation and puts stress on health workers. In addition, insufficient resources to support COVID-19 patients, families, and society in general, suffer anxiety. The lack of intensive care unit resources complicates the ethical issues that arise. There are several ethical procedures for allocating scarce resources. Some principles are inconsistent and will be explored later in other sections. For example, utilitarianism ethics maximizes economic interests, while egalitarianism emphasizes equality, needs, and opportunities. Finally, argument-based ethics and the cessation of medical support use various bioethical principles to control medical resources.

In contrast to utilitarian ethics, the research questions of this study focus on the moral view of any combination of bio and social ethics. The proposed triage methodology is unique in that it does not have any particular exclusion criteria. A few research on triage algorithms combine qualitative and quantitative methods to assess clinical and non-clinical ethical issues. In this investigation, we sketch a self-triage algorithm that is efficient, less complex, and simpler to implement. In addition, the algorithm is flexible enough to accommodate rapidly changing instructions and is agile enough to respond urgently. The research problems are as follows:

- Identify ethical criteria for triage screening and prioritization of patients;
- Construct an unbiased triage decision model taking into account clinical and non-clinical factors;
- Show unique data collection method with software and indicators of validation of data;
- Illustrate how the algorithm supports a robust triage decision model with case studies.

In section 1, briefly, the triage procedure and ethical guidelines are discussed. Then, the research issues are listed and outline the research questions. Section two includes the literature review. Part 3 deals with the practice of medical ethics during the pandemic. See section 4 for more details on the research objectives and questions. Unique data collection methods, including case descriptions, are listed in section 5, while section 6 describes research methods. Section 7 presents data analysis and algorithms. Section 8 summarizes the study with notes. Finally, in section 9, a list of references is provided.

2- Literature Review

The global pandemic COVID19 has changed all countries, transparently dealing with emergency medical systems. Patients with severe disease require special attention. Bed allocation in the ICU concerns health care facilitators based on equality of health care and ethical guidelines [14-20]. Countries severely affected are China, the United States, Italy, and Spain [15-17]. After the second wave of COVID-19, India is suffering a lot in all walks of life. These countries had to form rules for allocating scarce resources. ICU bed allocation, professional service, and life-supporting resource allocation have clinical and ethical consequences1. The resource allocation policy should be fair, and the general public should have access to this opportunity. There are several ethical approaches to allocating resources. Some principles are inconsistent. Utilitarianism insisted on maximizing profits. Equalitarianism emphasizes equality, needs, and opportunity [9, 18-19] discuss argument-based allocation of medical resources.

According to triage criteria, resource allocation guidelines determine which patients receive intensive care over others. Patients with a good prognosis are preferred [16]. This principle supports quantitative triage criteria and clinical judgment. Ethical considerations are the most promising prognosis concerning expected health outcomes regarding the quality of life and possible survival scenarios after intensive care. Severe comorbid disease, chronic disease, borderline age limit, predicted quality life expectancy, and complex illness denies ICU admission based on composite score [6, 20-22]. Clinical evaluation may be a questionable criterion since some ethical principles are general clinical decisions made by the patient [23]. Moral principles that consider race, gender, disability, religion, sexual orientation, or political opinion are unfair. Justice must come first to respect social dignity and human rights [4, 15, 24]. A utilitarian approach to maximizing profits during a pandemic is reasonable [25].

End-of-life care emphasizes options for suppression and cancellation of ICU treatment and is related to severe chronic diagnosis, need for ICU facilities, patient age, and religious beliefs [4, 5, 24]. Resource allocation based on social values such as dependents, social usefulness of patients, and economic benefits generated by patients is usually ignored and based on arbitrary decisions and discrimination. Measuring a person's worthwhile actions or social worth is difficult and often neglected. Although triage decisions aim to promote objective criteria, the social value of patients does not fall under these criteria [26].

Screening is critical for first-come-first-served patients or patients accessing a facility for the first time. Under this rule, the priority for patients with no or adverse prognosis is questionable. This policy could impose penalties on marginalized groups with low socioeconomic income. People suffer the disadvantage of not having access to information and access to medical systems [21, 27, 28]. The allocation of resources on the randomization process unintentionally benefits the patient. Factors such as ethnicity, sexual, racial, and socioeconomic status do not play any role, and all life is weighted equally. It eliminates biases discrimination, and everyone has an equal chance to access facilities. His rule can compete with the utility principle. Random assignments may not provide a reasonable resource allocation when saving more.

It is difficult to withdraw and maintain vital support treatment. In general, the decision reflects the patient's prognosis. The ethical principles of practical theory may be valid, but the considerations of moral ethics, religious ethics, and human dignity differ from decision-making processes. Other decision-making criteria create different results in triage decisions. The prioritization decisions that distinguish a person's eligibility for treatment depend on the benefit the patient may derive from treatment. Some patients may have a lower priority, so they can decide to treat them differently, receive treatment in the intensive care unit, or refuse mechanical ventilation. At times a patient feels disenfranchised for life-saving treatment due to pre-existing health problems. A policy that excludes the elderly, the disabled, the many health problems would be unfair. That is clear discrimination. A patient's ability to recover quickly compared to those with less rapid recovery is a discriminator [21, 29].

3- Research Inquiry of Medical Ethics

We discuss the ethical and procedural framework for prioritizing and screening patients during pandemic outbreaks such as COVID-19. The purpose is to describe a triage methodology that

- Is transparent in assigning patient priority;
- Follow ethical principles that integrate shared societal values, practices, and care for humanity;
- Maximizes effective use of essential resources, such as human capital, financial capitals; and critical infrastructures with informed prognosis;
- Enriches health service quality;
- Raise public confidence in policy decision-making;
- Improve public awareness of the global pandemic.

The triage process for COVID-19 emerges from two different stakeholders, namely, internal and external stakeholders. The internal stakeholder viewpoint considers collective bioethics in responding to an internal threat of a healthcare institution. The aim is to decide what is fair and just in a given situation for patient care. When considering external stakeholders, we focus on rationalizing the principles of bioethics and human dignity in the event of a conflict. There are ethical principles and values within each category that need attention.

3-1- Internal Considerations

In this case, the process of decision-making focuses on how the healthcare system in total interacts together to provide the best patient care under the constrained available resources. The following factors are in order.

- Nondiscriminatory: The triage process for implementing pandemic response measures must ensure proper medical care and justice for humans and assume appropriate responsibilities. Justify motives for the proposed decision.
- Unambiguous: Policies, treatment, and recommendations for ICU admission should be open to all interested parties.
- Completeness: Decisions should eliminate conflicts of interest involving the appropriate stakeholders.

- Reliability: The decision is consistent and robust. Ethical principles assessments must be supported by evidence of dignity in the event of a conflict.
- Integrity: Front-line healthcare workers should be assisted with an opportunity to maximize integrity, minimize moral distress and provide emotional support.
- Support: Teamwork between all stakeholders is vital to developing a fair decision support system.
- Agility: the healthcare systems should be systematic in infrastructure layout appropriate to respond to an emergency. Relevant stakeholders should define the line of authority and subordination without any duplication. The healthcare system should function effectively and remain available in the future as a sustainable process.
- Flexibility. The decision-making framework should adjust to the latest changes in case of unique knowledge circumstances and unexpected events.
- Rationality: Evaluations should be Rational and not arbitrary; there should be no subjective or administrative bias; it should be evidence-based feasible, and the decision is subject to review.

3-2- External Considerations

The critical ethical principles and values related to this category include:

- Equity: Society expects equidistribution of resources with justice. Some populations lack access to health care, regardless of ethnicity, socioeconomic status, structural inequalities in health, race, barriers to accessing health care services due to politics, location, age, disability, financial situation, health problems. When resources are limited, the principle of fairness will conflict in decision-making. In such a case, a decision should be considered equity, benefit, and harm to society.
- Dignity: Culture, norms, values of diverse populations should be considered as much as possible. Respect for individual privacy and confidentiality of personal information should prevail. Decisions based on beliefs, values, spirituality, culture, and literacy should consider a holistic societal view.
- Vulnerability: Care should be taken for economically, educationally, and geographically marginalized populations, and those who face severe burdens to access healthcare facilities, should be supported to minimize harm to society due to transmission of infection.
- Harm to society. Regulation should be in place to protect the general public from harm, injury, infection due to risk emanating from Covid-19, any other similar disease, and severe illness or death.
- The benefit to society: Society should focus on minimizing harm to the community while maximizing the benefits to the people with a decision, such as utilitarian principle, that fosters the overall health condition of the population. There will be a situation where striking a balance on this principle will be disturbing, but principles of social, ethical, moral, justice need careful evaluation in such circumstances.

3-3- Ethical Significance

The equal likelihood of survival of the patient, as a criterion, during an emergency or pandemic, is impartial. It does not include exclusion factors or non-clinical elements: religion, race, ethnicity, sexual orientation, social status, wealth, education, and quality of life. An ethical standard should guide a plan that reasonably recommends allocating critical resources. In emergencies, triage decisions should well define survival opportunities. Triage decisions should not focus just on long-term survival.

3-4- Utilitarianism

Utilitarian ethics holds that, in any case, a morally correct decision is a deliberation that produces the most significant benefit for all parties under consideration. Utilitarianism has some limitations when used as the sole method of ethical decision-making. Utilitarian estimation evaluates the benefits and costs in comparison with other alternative decisions. When the decision model assigns a monetary value to life, and human dignity, calculating and comparing the value of various benefits and costs is difficult, sometimes challenging, and controversial. If moral decisions include justice, the utilitarian principle itself cannot recommend, but it will influence the decision. The focus of Utilitarianism requires fair consideration of the direct, indirect, and long-term consequences of decisions that affect individuals, society, and families. The utilitarian principle requires to:

- Identify a variety of activities that one may take in a given situation;
- Analyze all potential benefits and problems of the given case;
- Suggest a course of action to produce the best results after considering all negative consequences.

3-5- Clinical and Non-clinical Factors

Based on the information in the preceding sections, the ethical factors for triage evaluation are shown in Table 1. They include clinical and non-clinical aspects. Figure 1 is the conceptual hierarchical triage evaluation process.

Table 1. Comorbidity: Descriptions and Operationalization of critical criteria to determine patient priority

Factor	Sub-Factor	Item	Scale
PF1		**"Disease severity (Prognosis / Comorbidity) Score based on overall conditions of a patient" (PF1.1 to PF1.17)**	**1=Less Severe; 9=Severe disease**
	PF1.1	"Cancer"	1=Early stage; 9=Advance Stage
	PF1.2	"Chronic kidney disease"	-
	PF1.3	"Chronic lung diseases, including COPD (chronic obstructive pulmonary disease), asthma (moderate-to-severe), interstitial lung disease, cystic fibrosis, and pulmonary hypertension"	1=Low; 9=High
	PF1.4	"Neurological conditions: Dementia"	1=Low; 9=High
	PF1.5	"Diabetes"	1=Low; 9=High
	PF1.6	"Down syndrome"	1=Low; 9=High
	PF1.7	"Heart conditions (such as heart failure, coronary artery disease, cardiomyopathies, or hypertension)"	1=Low; 9=High
	PF1.8	"HIV infection"	1=Low; 9=High
	PF1.9	"Immunocompromised state (weakened immune system)"	1=Low; 9=High
	PF1.10	"Liver disease"	1=Low; 9=High
	PF1.11	"Overweight and obesity"	1=Low; 9=High
	PF1.12	"Pregnancy"	1=Low; 9=High
	PF1.13	"Sickle cell disease or thalassemia"	1=Low; 9=High
	PF1.14	"Smoking"	1=Low; 9=High
	PF1.15	"Solid-organ or blood stem cell transplant"	1=Low (Simple); 9=High (complex)
	PF1.16	"Stroke or cerebrovascular disease"	1=Low; 9=High
	PF1.17	"Substance use disorders: (alcohol, opioid, or cocaine use disorder)"	1=Low; 9=High
PF2		**"Response to treatment"**	-
	PF2.1	"Sign of improvement (Probability of improvement due to treatment)"	1=Good sign; 9=Poor sign
	PF2.2	"Difficulty in doing activities independently" (High -Low)	1=Easy of doing the task; 9=need assistance
PF3		**"Age: (Diagonosis Purpose)"**	**1=Young; 9=Advanced age**
PF4		**"Dependent Responsibility (caring for someone else)"**	-
	PF4.1	"Maternal and infant care"	Yes/No (Score No=1, Yes=9)
	PF4.2	"Dependent family members (They need support) "	Yes/No (Score No=1, Yes=9)
PF5		**"Surgery: if and when necessary."**	**1=High Success; 9=Low Success**
	PF5.1	"No Willing to do surgery (Patient)"	Yes/no (score No=1, Yes=9)
	PF5.2	"Chance of successful surgery"	1=high chance; 9=poor chance
PF6		**"Rehabilitation support (Available): Resilience, Recovery."**	-

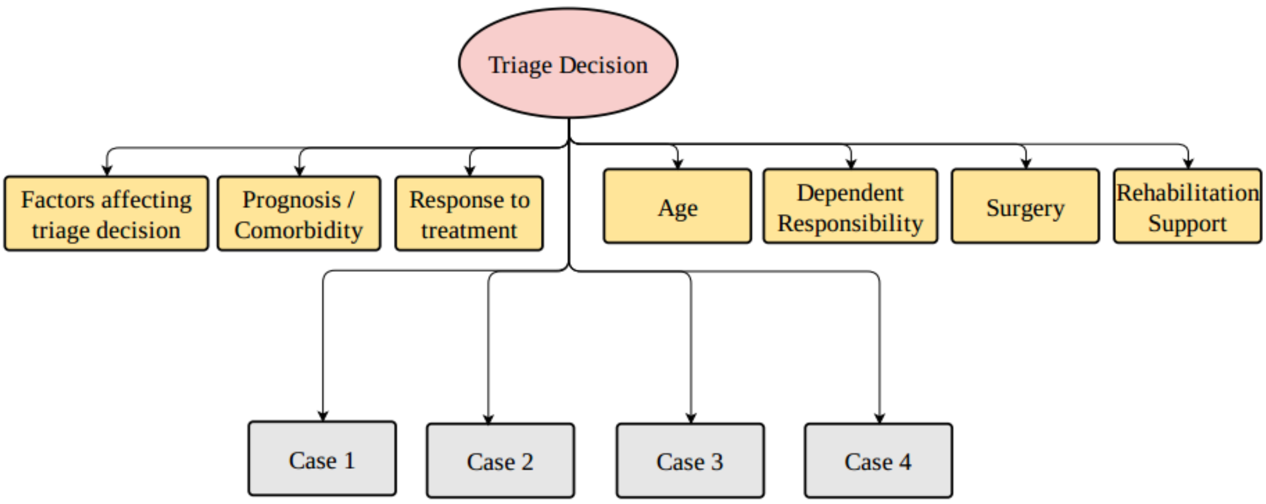

Figure 1. Hypothesized Decision-Making Research Framework

4- Research Questions

Clinicians and policymakers require urgent patient review due to the nature of COVID-19 infection. Aziz et al. [30] recommend that COVID-19 patients be managed in intensive care facilities. The issues cover planning, response policies, family support, triage, and staff. Hulsbergen et al. [31], present an overview of ethical triage and discuss the main ethical principles relevant when allocating resources. They discuss a framework of four principles: maximizing benefits, prioritizing the worst off, equality inpatient treatment, and encouraging instrumental value. They also discuss screening with age criteria and comorbidity. Still, stress that some intuitive factors do not form a basis for triage. Mohammed et al. [32] reviewed extensive literature and reported studies on triage and prioritization.

The two research discuss triage [33, 34], and prioritization [33] solutions for patients with chronic heart disease as a case study. However, they claim that these research did not aim at the combination between triage and prioritization. In comparison, Vinay et al. [35] discuss controversial criteria triage guidelines from professional and governmental bodies. The article discusses patient admission policies, including medical prognosis, life expectancy, age, quality of life, and ethical principles. In addition, this studies the convergence and divergence points in the shunting agreement and examines the moral debates related to them. Finally, Camporesi and Mori [36] highlighted Italian doctors' ethical dilemmas and the challenges during the Covid19 epidemic. They claim that "rationing critical healthcare resources is not typically a feature of healthcare systems in high-income countries, and many doctors in Italy had to decide life/death decisions for the first time." According to this study, the critical resource shortage and the utilitarian triage can ethically justify the 'exceptionality' of the difficult time. The report stresses the need for an unbiased triage protocol.

None of the articles reported on a combination of qualitative and quantitative methods to develop an algorithm for triage and scoring clinical and non-clinical issues. This research outlines a unique methodology and presents a triage algorithm that is efficient and easy to implement without much complexity. Furthermore, the algorithm is flexible enough to accommodate rapidly changing guidelines and agile enough to respond to an urgent situation. Moreover, the methodology engages all stakeholders in decision-making. Hence, it minimizes stress among the health professional. In the future, and currently in this study, we will explore further potential research issues.

The moral dilemma with the front-line medical workers in an ICU poses ethical and legal challenges. Due to limited time, critical resources, supporting infrastructure, and human capital to support urgent medical care, the decision-making is complex. A fair triage process is likely to reduce stress for the decision-makers so that it is defensible, decision making is open, accountable, transparent, and involves essential stakeholders [37]. Equal distribution of resources is necessary for fairness. The moral dilemma arises due to the pandemic's disproportionate health care support facilities. The likely impact would be on communities of color, people with income disparity, individuals in nursing care facilities, homeless people, and people with inadequate government documents. Universal ethical policies should aim at equitable distribution of necessary resources to respond to a pandemic. The front-line medical workers deal with stress, anxiety, and concern for their wellbeing. In extreme events and acute conditions during a pandemic, the triage decision-making raises questions about legal issues, liability, professional practice, and job security. The inherent dignity of each suffering from infections, the linkage between people, forced isolation, social distancing, and adhering to hygiene protocol reflect unity and solidarity in the community [37].

Due to the stress among the medical professionals and infected patients, the research problems contain other medical decision processes that lead to a COVID-19 patient triage algorithm. A robust method of decision-making involving appropriate stakeholders, without any bias, will reduce the burden of anxiety among medical professionals and patients alike. The research questions, therefore are, how to:

- Identify criteria for triage screening and prioritize patients,
- Construct an ethical decision support system (DSS) taking into account several medical and non-medical factors to rank patients in the triage process,
- Collect data with case studies for triage DSS model and data analysis,
- Design an unbiased triage algorithm to admit ICU patients,
- Illustrate how the algorithm supports a robust triage decision model.

4-1- Data Collection for Triage Evaluation

Triage decision is critical and complex. This study shows a multicriteria triage policy to provide rational decisions considering all possible patient conditions. The hierarchy formation is necessary to collect data with a Delphi approach to evaluate a patient score for triage decisions. We use a case study on patient conditions listed in Tables 1 and 2 and Figure 1 hierarchically ethical factors in evaluating patient scores. The decision hierarchy is formed by analyzing information on a patient by a team of experts and a moderator who guides the evaluation and data collection process. The methodology presents questions to the expert evaluators' questionnaire in a pairwise comparison matrix. All factors and sub-factors form a hierarchal structure for data evaluation by employing a pairwise comparison assessment matrix [38-42] (Table 3). The questions offer a set of comparison elements, and a decision-maker records judgment score with a scale ranging from one to nine. The rankings are provided in a matrix form, as shown in Table 4. The matrix order (n × m) varies on the number of experts involved in decision-making and factors listed for evaluation (Table 1). The factor elements are subdivided into subfactors for further analysis and guide for data entry assistance. The assumption is that if a factor "A" is "absolutely more important" against the factor "B" and suppose that a score of 9 is assigned, then the factor "B" should be "absolutely less important" compared to factor "A" and the rating 1/9 is assigned. As per Table 5 and Table 6 scale, all elements are compared pair by pair. The input values form a particular matrix pattern. This scale is applicable for quantitative and qualitative criteria. It is possible to use verbal responses intuitively to enable some ambiguity in non-trivial comparisons.

Table 2. Case Data

Patient	Age.	Sex	Comorbidities	Other Conditions
#(ICU)	Years		Description	
ICU#1	77	Female	A female patient who has a health problem with high blood pressure and hyperlipidemia is admitted to the emergency section from a primary care unit. She is 77-year-old. Few people at the primary care unit are COVID-19 positive. She had no direct contact with them. Later, she had a temperature of 102°F and was referred to the ED. she was found to have a chest infection and sporadic fever. She had weakness, cough, tiredness, and palpitation. She tested positive, later, with COVID-19. During admission, she had a 101°F temperature. Her blood pressure reading is 148/76 mm Hg. The heart rate per minute is recorded at 100. The respiratory rate is 20/minutes. At room air, the saturation of oxygen level is 95%. A chest X-ray showed a prevalence of lung infection. The patient was admitted for possible pneumonia and had doubts about the COVID-19 infection. After 2 days, the patient's condition deteriorated. She is now found to have hypoxic to 85% oxygen saturation. She has a fever reaching 104°F. She is intubated. Directly, she is transferred to the ICU. The patient's condition remained critical in ICU.	He has a large extended family. She is caring for the family members as and when required. She assists the family in household works. She is a role model and integrates the family socially.
Similar other ICU admissions are listed briefly for the case study				
ICU#2	62	Male	Osteoporosis, hypertension, hypercholesterolemia, diabetics, dementia	He is a Banker and Financial investment specialist. He is single.
ICU#3	80	Female	Osteoporosis, hypertension, hypercholesterolemia, fracture, chronic obstructive pulmonary disease	She is a couple and living in a home and has a spouse. They are mutually supporting each other.
ICU#4	89	Female	Osteoporosis, hypertension, hypercholesterolemia, fracture	She lives in an old-age care facility. She is alone and has distant relatives.
New Cases				
Case 1	35	Male	The emergency department calls the ICU to admit a patient in the emergency room with a severe reversible brain injury after an automobile accident. He is young and is a driver. He got infected with COVID 19 from the passenger.	He has a wife and two young children at home. He is the only bread earner.
Case 2	70	Male	A highly specialist medical practicing doctor, a cardiologist, got infected with COVID 19. His health condition is deteriorating day by day. He needs immediate ventilator support. He has diabetes but is in a steady state.	He has two grown-up children and a wife. They are independent. His service in a hospital is necessary. He has a happy family.
Case 3	46	Female	A female teacher is COVID-19 Positive. She has diabetes and has other medical conditions: She is overweight and suffers from hypertension.	She has three children and looks after the family, including her older parents. She is a single mother. She is financially well.
Case 4	83	Male	He is an entrepreneur and a social worker affiliated with NGO, providing support to the community. He is suffering from osteoporosis, hypertension, hypercholesterolemia, lumber plexopathy, atrial fibrillation. Due to his social work activities, he is now a covid-19 patient.	He lives with extended family and runs a successful business employing several people. His business skills and advisees are necessary to run the business operations.

Table 3. Data Entry Screen: Systematic Factor Comparison

Factor Computation	Expert: 1	α=0.1	CR=97%	Which is more important?
A		**B**	**A or B?**	**Scale: 1-9**
1) "Prognosis/Comorbidity"	Compare with	2) "Response to treatment"	B	5
		3) "Age: (Diagnosis Purpose)"	A	4
		4) "Dependent responsibility"	B	1
		5) "Surgery: if and when necessary."	A	2
		6) "Rehabilitation support"	B	4

2) “Response to treatment”	Compare with	3) “Age: (Diagonosis Purpose)”	A	9
		4) “Dependent Responsibility”	A	3
		5) “Surgery: if and when necessary.”	A	5
		6) “Rehabilitation support”	B	1
3) “Age: (Diagonosis Purpose)”		4) “Dependent Responsibility”	B	4
		5) “Surgery: if and when necessary.”	B	7
		6) “Rehabilitation support”	B	5
4) “Dependent Responsibility”		5) “Surgery: if and when necessary.”	A	2
		6) “Rehabilitation support”	B	5
5) “Surgery: if and when necessary.”		6) “Rehabilitation support”	B	4

Table 4. Decision Matrix A (Expert: 1 and 2)

Criterion	Prognosis & comorbidity	Prognosis & comorbidity	Response to Treatment	Response to Treatment	Age	Age	Dependent Responsibility	Dependent Responsibility	Surgery	Surgery	Rehabilitation support	Rehabilitation support	Normalized Score: Expert:1	Normalized Score: Expert:2	Normalized Score: Expert:1&2
Expert (1 & 2)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1&2
Prognosis & comorbidity	1	1	0.2	0.11	4	3	1	0.5	2	0.33	1	0.2	0.136	0.056	0.0892
Response to Treatment	5	9	1	1	9	5	3	5	5	5	1	5	0.358	0.500	0.4413
Age	0.25	0.33	0.11	0.2	1	1	0.33	0.5	0.14	0.5	0.2	0.2	0.033	0.046	0.0399
Depend. Responsibility	1	2	0.33	0.2	3	2	1	1	2	1	0.2	0.5	0.106	0.102	0.1067
Surgery	0.5	3	0.2	0.2	7	2	0.5	1	1	1	0.25	1	0.086	0.122	0.1028
Rehabilitation support	1	5	1	0.2	5	5	5	2	4	1	1	1	0.281	0.174	0.22
SUM													1	1	1
CR:	0.079	0.063													
GCI: (Group)	0.1055														
CR: (Group)	0.028														
Lambda: (Eigen Value)	6.1782														
Shannon Entropy	α =	4.464		β =	1.021		γ =	4.559							
Mean Relative Error	26.8%														
Consensus (Group):	95.2%														

Table 5. Data Collection Reciprocal Scale

Preference Level	Scale	Interpretation
Equally Preferred	1	The two compared factors contribute equally to the objective
Equally to Moderately Preferred	2	Intermediate values between the two adjacent judgments. The scale is applied when a middle ground is desirable.
Moderately Preferred	3	From previous experiences and facts, one factor is to some extent favored over the other
Moderately to Strong Preferred	4	Intermediate values between the two adjacent judgments. The scale is applied when a middle ground is desirable.
Strongly Preferred	5	From previous experiences and facts, one factor is strongly favored over the other
Strongly to Very Strongly Preferred	6	Intermediate values between the two adjacent judgments. The scale is applied when a middle ground is desirable.
Very Strongly Preferred	7	From previous experiences and facts, one factor is very convincingly favored over the other. Several times, the importance is demonstrated
Very Strongly to Extremely Preferred	8	Assign values in-between the two neighboring judgments. The scale ensues when an intermediate range is desirable.
Extremely Preferred	9	The highest probability and with confidence one factor are favored over the other
Reciprocals		Suppose a factor, denoted as “*i*”; has a rated value allocated to “*i*” when evaluated by the activity number, say; “*j*”; at that time, “*j*” will have the multiplicative inverse value after being matched through the corresponding element, “*i*”. Thus, the diagonal elements in the data matrix are recorded as inverse values.

Table 6. Guideline: Expert Opinion and Recommendation in a Pairwise Evaluation of Assessment

In case of Factor A is more important than Factor B, please suggest and record a score (One value from 1 to 9)																	
		Measure: 1 = Alike		3 = Reasonable		5 = Strong		7 = Especially Strong		9 = Maximum							
			Most Significant						**Alike**						**Most Significant**		
Factor																	
1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
	A		⇐……………………………………..						↔		…………………………………⇒					B	
In case of Factor B is more important than Factor A, please suggest and record a score (One value from 1 to 9)																	
		Measure: 1 = Alike		3 = Reasonable		5 = Strong		7 = Especially Strong		9 = Maximum							
			Most Significant						Alike						Most Significant		
Factor																	
1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
	A		⇐……………………………………..						↔		…………………………………⇒					B	

5- Primary Data Collection

Table 1 lists factors that are likely to impact the patient's priority. It includes clinical and social factors considering human dignity and social ethics. IIn stage one, these factors are prioritized to initiate the triage algorithm. The bottom row in the hypothesized model includes the four ICU admitted patients (Table 2). In stage two, the algorithm evaluates the cases of each patient with the six predefined criteria. Finally, stage three involves ranking the four patients based on the six clinical and non-clinical criteria.

5-1- Data Clinical and Non-clinical Factors Leading to Ethical Considerations

Table 1 summarizes the clinical and non-clinical factors for triage and patient screening based on the discussions in sections 2 and 3. There are six factors identified as PF1, PF2,...., and PF6. In addition, sub-factors can exist for each element. This factor information on comorbidity, along with explanations and pertinent information, is provided to experts to assess a patient's condition. Table 2 lists the needs of the patients' cases.

5-2- Case study - Priority Setting in an ICU and Initial Scenarios

Hospitals in developing countries specialize in trauma treatment and have large emergency rooms. The ICU is supporting the hospitals. In a COVID-19 outbreak, hospitals will transform to provide care for COVID19 patients. All patients of any age are competing for ICU. A patient of 65 years or older with certain medical conditions is at risk of contracting COVID-19. Patients may require instrumentation that entails hospitalization and special attention intensive care for severe complications and may face life-threatening situations, including death [43-48]. The ICU is operating at maximum capacity. The occupancy rate is at the lowest.

Scenario 1: The ICU facility is in total capacity (No Occupancy);

Scenario 2: Just now, an ICU patient passes away. There is now a bed available;

Scenario 3: Few patients in ICU have complex comorbidity and poor prognosis.

Question: How the emergency support will allocate resources to the potential new admitted covid-19 patient?

Rationale: By combining utilitarian ethics, defined as the pursuit of the greatest good for the most significant number, and agnostic ethics conceptualized as a principle that claims the existence of God, we can rank all the potential covid-19 patients by using a multicriteria assessment method.

5-3- Data Collection Process

The scales shown in Table 5 and Table 6 are the first step necessary for data collection. Critical criteria or elements of judging are weighted using expert opinion. The scale ranges between 1 to 9. Table 3 shows the data entry mode using pairwise comparison of factors. Table 7 shows how pairwise comparisons between factors. Data collection is in [n × m] matrix format. The diagonal elements of the factor have reciprocal values. Table 8 is a typical example of basic data entry. Pairwise comparison between two competing factors one at a time determines expert opinion. This data is necessary to calculate the prognostic factor score (PF1) to rank the severity and severity of the patient's illness described in Cases 1, 2, 3, and 4. The data and algorithm rank the morbidity factors PF1.1 through PF1.17 based on the scores obtained in expert opinion.

Table 7. Pairwise comparison matrix (Factor and Criteria)

$$\left\{ \begin{array}{ccccccccc} Cri\rightarrow & C_1 & C_2 & C_3 & C_4 & C_5 \cdot\cdot & \cdot\cdot & C_k \\ Alt\downarrow & w_1 & w_2 & w_3 & w_4 & w_5 \cdot\cdot & \cdot\cdot & w_J \\ A_1^r & a_{11}^r & a_{12}^r & a_{13}^r & a_{14}^r & a_{15}^r \cdot\cdot & \cdot\cdot & a_{1J}^r \\ A_2^r & a_{12}^r & a_{22}^r & a_{23}^r & a_{24}^r & a_{25}^r \cdot\cdot & \cdot\cdot & a_{2J}^r \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots\ \vdots & \vdots & \vdots \\ A_I^r & a_{I1}^r & a_{I2}^r & a_{I3}^r & a_{I4}^r & a_{I5}^r \cdot\cdot & \cdot\cdot & a_{IJ}^r \end{array} \right\}$$

Table 8. Decision Matrix (Factor Comparison between elements) Expert:1

	Prognosis & comorbidity	Response to Treatment	Age	Depend. Responsibility	Surgery	Rehabilitation support
	1	2	3	4	5	6
1	**1**	0.2	4	1	2	1
2	5	**1**	9	3	5	1
3	0	0.111111	**1**	0.33	0.143	0.2
4	1	0.333333	3	**1**	2	0.2
5	1	0.2	7	0.5	**1**	0.25
6	1	1	5	5	4	**1**

The second step involves experts' opinions recorded back into the software (Table 3) to evaluate and prepare pairwise comparison factor: PF1 to PF6. This step aims to determine the priority among the individual factors (PF1, PF2, ..., PF6). The reliability and consistency of data collection and data analysis are discussed later.

In the third phase, patients with each patient's case reported in the ICU are estimated with factors PF1, PF2, ..., PF6. Finally, experts enter opinions as a ranked value in the software [38] as comparison scores between factors for each patient.

In the fourth step, the algorithm evaluates the internal consistency of the data and the test for group consensus between experts (Equations 1 to 5, and "CR", Consistency ratio, in Table 9). Results are tested for consistency ratio, group consensus, and patient priority. Reliability of expert response, validation, and internal data accuracy are discussed in Section 8 of the methodology. For decision-making, this algorithm determines a triage score. CR measures the accuracy of an assessment with a sample of random decisions. Expressed opinions with a CR significantly greater than 0.1 are unreliable, and thus, data show randomness. In other words, the data is inconsistent, and a reevaluation is preferred.

Table 9. Consistency Ratio Measurement with Random Indices (n = 1 to 10) [45, 46]

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

5-4- Data Collection Software

Decision support systems in medical applications are available in the literature with diverse issues [35-44]. But the quantification of triage decisions with ethical issues is rare in literature. The "analytic hierarchic" process is one of the DSS that systematically analyzes the judgments of several experts for unbiased decisions [36, 40]. But there is rare literature that illustrates ethical triage sequential decision incorporating clinical and non-clinical ethical factors. This study will identify a triage algorithm that will consider necessary medical conditions present or absent among the patients to evaluate and rank based on the survival chance, social factor, and human dignity. The sequential analysis illustrates the ranking of decisions with four unique patients.

We analyze case studies of ICU patients in a combination of Delphi approach bioethics and social ethics criteria. Brainstorming sessions are planned with medical experts in virology and intensivist to collect data. Table 8 is an illustration of a data collection format. The evaluation between ethical factors is a unique documentation technique for collecting data. The computer software helps organize data in tabular and matrix form [38]. The Delphi data collection method involves brainstorming sessions with two experts. In phase one of the data collection, the experts get assistance with the software to decide the significance and weightage of the ethical factors under consideration. The triage model records data with the estimates of the pairwise evaluation of factors attributes for the six classified criteria., the relative weights of the factor elements are first assessed from the inputs judged by the experts, as shown in Table 4.

5-5- Secondary Data

The medical history of patients determines the patient condition and status. Further, the clinical data are reviewed in light of the factors for triage decisions. Finally, the software input is gathered from expert opinion on the social-ethical aspects and patient conditions by factor-wise comparison.

6- Research Methodologies

Consider that $j=n$ number of criteria elements are compared, $C_1, C_2..., C_j$, and when compared pairwise, a matrix of $[j\ x\ j]$ is formed in terms of the relative comparison score. Define priority or relative "weight" of the element C_i for C_j with $[a_{ij}]$ and document a matrix that is a square in nature, $A=[a_{ij}]$, of order j. The desirable requirement is that all the element $a_{ij}^r = \frac{1}{a_{ji}^r}$; for all $i \neq j$, and all $a_{ii} = 1$. It should form a reciprocal $[a_{ij}]$ matrix, where $r=1,2....,R$, indicating the $[a_{ij}]$ matrix is the input from r^{th} respondent. The notation $A_1, A_2, ...,.A_I$; suggests alternatives $i=1,2,....I$; and the notation $C_1, C_2, ...,.C_J$; shows evaluation criteria $j=1,2,....J$. The pairwise performance evaluation of alternatives A_i under criteria C_j is denoted by $[a_{ij}]$. The $[a_{ij}]$ pairwise comparison matrix elements are the rank score between alternatives i and j, evaluated by respondent number or expert number r. the vector index w_j represents the weight of the criterion C_j and the sum of all weight equal to one [45, 46] $\left(\sum_{j=1}^{J} w_j^r = 1\right)$. Normalizing the evaluation score allows the data to be a dimensionless entity to compare the criteria. The normalized vector is defined as $\hat{a}_{ij}^r = \frac{a_{ij}^r}{\sum_{i=1}^{I} a_{ij}^r}\ (j = 1,2,...,.J)$. The priority is defined as $p_i^r = \frac{\sum_{j=1}^{J} \hat{a}_{ij}^r}{J}$.

The weights are consistent such that the necessary condition for matrix $[a_{ij}] = [a_{ik}a_{kj}]$ is valid for all i, j, and k (Element "i" is compared with element "j" and k denoting the number of elements or criteria). The pairwise comparison matrix score is consistent if for all comparison $[a_{ij}]$ follow the transitivity rule ($[a_{ij}] = [a_{ik}a_{kj}]$) and reciprocity condition [47-50] $\left(a_{ij}^r = \frac{1}{a_{ji}^k}\right)$.

Let, $j=n$ for a national purpose, where n number of elements need a comparison. The eigenvector "ω" of order n will have an and eigenvalue "λ" such that $A\omega = \lambda\omega$. For the matrix, $A=[a_{ij}]$, and $\lambda = n$. Data entry in matrices includes human judgments by participants. The judgments are unreliable if the condition $[a_{ik}] = [a_{ij}a_{jk}]$ does not hold to a large extent. The vector "ω" may fulfill the equality $\{A\omega= \lambda_{max}\omega\}$, and that $\{\lambda_{max} \geq n\}$ is valid. Among "λmax" and "n" the variance shows the measure of discrepancy in judgments. The judgment is consistent if the expression $\{\lambda_{max} - n=0\}$ holds [35]. The maximum eigenvalue is $(\lambda_{max}) = \sum_{i=1}^{n} w_i c_i$. The index "$w_i$" is the weight or priority vector, and the index c_i; defines the sum of the column. The CI, Consistency Index computes CI as $= \frac{\lambda_{max} - n}{n-1}$. The Consistency Ratio (CR) is obtained by taking the ratio between the CI for the set of judgments and RI; the Random Consistency Index; for the matching random index defined as $CR = \frac{CI}{RI} < 0.10$. The RI is available from Table 9. If the CR >0.1, the decisions are unpredicted, and conclusions are unreliable [51]. In practice, CR values > 0.1 sometimes are accepted due to the complexity of the data collection method involving expert opinion [52]. If $CR = 0$, it implies that the judgment is entirely consistent. The group consensus indicator is the Shannon beta entropy [53] for n number of criteria and k number of participants. Thus, decision-making and Group Consensus Indicator (GCI) express Shannon beta, gamma, and alpha entropy.

Shannon BETA entropy $H_\beta = H_\gamma - H_\alpha$ (1)

Shannon ALPHA entropy, defined as: $H_\alpha = \frac{1}{k}\sum_{i=1}^{k}\sum_{j=1}^{n}[-w_j\ ln(w_j)]$ (2)

Shannon GAMMA entropy, defined as: $H_\gamma = \sum_{i=1}^{n}[-w_{avg}\ ln(w_{avg})]$ (3)

$$w_{avg} = \frac{1}{k}\sum_{j=1}^{k} w_{jk} \quad (4)$$

$$w_i = \frac{\sum_{j=1}^{n} a_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}} \quad (5)$$

The test of CR is useful in decision-making. A higher consistency ratio; CR > 10%; implies an unreliable outcome.

Accumulation of individual judgments by experts is calculated with a geometric mean of all decision matrices to derive a group consensus indicator (GCI). The value of the GCI ranges from 0% to 100%. A value corresponding to 0% implies no consensus, while a 100% GCI shows complete agreement. The Shannon alpha and beta entropy (Equation 1) computes the GCI, which measures the consistency of priorities between the participants. In addition, the GCI measures the degree of inconsistency in assessments and the convergence of expert assessments among members involved in decision-making. We derive GCI from Shannon's alpha, beta, and gamma entropies (Equations 1 to 5). It determines the convergence of the respondents' consensus. A consensus score >75% is judged reliable. As an example, Tables 10 to 13 and Table 14 have a consensus score above 90%, while the consensus score in Table 15 is below 90%. The score is 86.3%. Therefore, there is minor concern about patient case 3 between the experts. However, it implies there is some conflict of opinion between the experts.

Table 10. **Decision Matrix A: About Patient Case 1 (Expert 1 and 2)**

Criterion	Prognosis & comorbidity	Prognosis & comorbidity	Response to Treatment	Response to Treatment	Age	Age	Dependent Responsibility	Dependent Responsibility	Surgery	Surgery	Rehabilitation support	Rehabilitation support	Normalized Score: Expert:1	Normalized Score: Expert:2	Normalized Score: Expert:1&2
Expert (1 & 2)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1&2
Prognosis & comorbidity	1.00	1.00	0.33	3.00	0.20	1.00	0.13	0.50	0.14	3.00	0.5	1.00	0.036	0.161	0.09
Response to Treatment	3.00	0.33	1	3.00	0.33	0.20	0.17	0.14	0.33	0.20	0.33	0.20	0.064	0.035	0.05
Age	5.00	1.00	3	3.00	1.00	1.00	0.33	0.20	0.2	0.50	0.33	0.25	0.103	0.093	0.11
Dependent Responsibility	8.00	2.00	6	3.00	3.00	5.00	1.00	1.00	0.33	5.00	2	3.00	0.247	0.387	0.34
Surgery	7.00	0.33	3	3.00	5.00	2.00	3.00	0.20	1	1.00	4	0.20	0.409	0.095	0.21
Rehabilitationn support	2.00	1.00	3	3.00	3.00	4.00	0.50	0.33	0.25	5.00	1	1.00	0.141	0.229	0.2
SUM													1	1	1
CR:	0.095	0.082													
GCI: (Group)	0.233														
CR: (Group)	0.063														
Lambda: (Eigen Value)	6.3978														
Shannon Entropy	α = 4.614			β = 1.094			γ = 5.049								
Mean Relative Error	0.395														
Consensus (Group):	0.801														

Table 11. **Decision Matrix A: About Patient Case 2 (Expert 1 and 2)**

Criterion	Prognosis & comorbidity	Prognosis & comorbidity	Response to Treatment	Response to Treatment	Age	Age	Dependent Responsibility	Dependent Responsibility	Surgery	Surgery	Rehabilitation support	Rehabilitation support	Normalized Score: Expert:1	Normalized Score: Expert:2	Normalized Score: Expert:1&2
Expert (1 & 2)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1&2
Prognosis & comorbidity	1	1	0.25	3	0.143	0.333	1	1	1	1	0.2	0.5	0.064	0.115	0.09
Response to Treatment	4	0.333	1	1	0.5	0.2	1	1	1	1	1	0.167	0.164	0.057	0.05
Age	7	3	2	5	1	1	1	3	1	5	0.5	0.333	0.202	0.251	0.11
Dependent Responsibility	1	1	1	1	1	0.333	1	1	1	1	0.2	0.143	0.112	0.072	0.34
Surgery	1	1	1	1	1	0.2	1	1	1	1	0.333	0.143	0.122	0.066	0.21
Rehabilitation support	5	2	1	6	2	3	5	7	3	7	1	1	0.337	0.439	0.2
SUM													1	1	1
CR:	0.089	0.055													
GCI: (Group)	0.1170														
CR: (Group)	0.032														
Lambda: (Eigen Value)	6.1978														
Shannon Entropy	α = 4.861			β = 1.027			γ = 4.99								
Mean Relative Error	0.282														
Consensus (Group):	0.940														

Table 12. Decision Matrix A: About Patient Case 3 (Expert 1 and 2)

Criterion	Prognosis & comorbidity	Prognosis & comorbidity	Response to Treatment	Response to Treatment	Age	Age	Dependent Responsibility	Dependent Responsibility	Surgery	Surgery	Rehabilitation support	Rehabilitation support	Normalized Score: Expert:1	Normalized Score: Expert:2	Normalized Score: Expert:1&2
Expert (1 & 2)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1&2
Prognosis & comorbidity	1	1	1	3	0.33	3	0.2	0.33	1	1	0.25	1	0.070	0.163	0.11
Response to Treatment	1	0.33	1	1	2	0.33	0.33	0.33	1	1	2	0.2	0.145	0.060	0.1
Age	3	0.33	0.5	3	1	1	0.33	0.33	5	1	2	0.2	0.181	0.086	0.13
Depend. Responsibility	5	3	3	3	3	3	1	1	4	3	3	0.5	0.395	0.251	0.33
Surgery	1	1	1	1	0.2	1	0.25	0.33	1	1	0.33	0.14	0.070	0.081	0.08
Rehabilitation support	4	1	0.5	5	0.5	5	0.33	2	3	7	1	1	0.138	0.359	0.24
SUM													1	1	1
CR:	0.087	0.081													
GCI: (Group)	0.1017														
CR: (Group)	0.027														
Lambda: (Eigen Value)	6.1713														
Shannon Entropy	α = 4.944			β = 1.063			γ = 5.255								
Mean Relative Error	0.261														
Consensus (Group):	0.863														

Table 13. Decision Matrix A: About Patient Case 4 (Expert 1 and 2)

Criterion	Prognosis & comorbidity	Prognosis & comorbidity	Response to Treatment	Response to Treatment	Age	Age	Dependent Responsibility	Dependent Responsibility	Surgery	Surgery	Rehabilitation support	Rehabilitation support	Normalized Score: Expert:1	Normalized Score: Expert:2	Normalized Score: Expert:1&2
Expert (1 & 2)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1&2
Prognosis & comorbidity	1	1	0.111	7	0.111	0.143	1	1	0.2	1	0.111	0.143	0.027	0.102	0.05
Response to Treatment	9	0.143	1	1	0.2	0.2	3	2	3	2	0.333	0.333	0.139	0.083	0.1
Age	9	7	5	5	1	1	8	8	7	7	0.5	1	0.347	0.364	0.37
Depend. Responsibility	1	1	0.333	0.5	0.125	0.125	1	1	0.333	1	0.143	0.111	0.035	0.046	0.04
Surgery	5	1	0.333	0.5	0.143	0.143	3	1	1	1	0.143	0.143	0.071	0.049	0.06
Rehabilitation support	9	7	3	3	2	1	7	9	7	7	1	1	0.381	0.356	0.38
SUM													1	1	1
CR:	0.079	0.082													
GCI: (Group)	0.1207														
CR: (Group)	0.033														
Lambda: (Eigen Value)	6.2049														
Shannon Entropy	α = 4.106			β = 1.016			γ = 4.172								
Mean Relative Error	0.29														
Consensus (Group):	0.963														

Table 14. Patient Rank with the Multi-Factor Triage Algorithm, (MUFTA) (Expert 1)

Patient	Respondent 1						
	Prognosis & comorbidity	Resp.Treat	Age	Depend.Resp.	Surgery	Rehab.support	Normalized Rank
Case: 1	0.036	0.064	0.103	0.247	0.409	0.141	0.181
Case: 2	0.064	0.164	0.202	0.112	0.122	0.337	0.326
Case: 3	0.070	0.145	0.181	0.395	0.070	0.138	0.356
Case: 4	0.027	0.139	0.347	0.035	0.071	0.381	0.137

Table 15. Patient Rank with the Multi-Factor Triage Algorithm, (MUFTA) (Expert 1 and 2)

Patient	Consolidated (Respondent 1 & 2)						
	Prognosis & comorbidity	Resp.Treat	Age	Depend.Resp.	Surgery	Rehab.support	Normalized Rank
Case: 1	0.086	0.051	0.111	0.345	0.208	0.199	0.281
Case: 2	0.086	0.1	0.237	0.092	0.09	0.395	0.280
Case: 3	0.086	0.1	0.237	0.092	0.09	0.395	0.280
Case: 4	0.048	0.098	0.369	0.042	0.063	0.379	0.158

7- Data Analysis

The algorithm uses qualitative and quantitative data in a matrix, and ranked order information is derived. This algorithm transforms a complex problem into interpreting details in a hierarchy. First, the triage issue forms sub-problems into various stages such that it forms a hierarchical pairwise relationship for data acquisition. Next, create a feedback structure for judgments by comparing factors pair by pair to a ratio scale, taking one patient at a time. Finally, the factor scores are analyzed systematically to build a decision alternative. The uppermost of the hierarchy is the critical aim of a triage decision. The lowermost levels are the clinical, non-clinical, and secondary criteria that impact the purpose. Finally, the bottom level forms a structure to compare the secondary criteria for evaluating the decision. Thus, the algorithm conceptually involves four main phases.

In phase 1, the expert judges compare factors pairwise, and the software estimates a normalized weight [38]. Normalization is a dimensionless process, resulting in a scalar quality for unbiased decisions. As illustrated in Table 5, the scale assigns pairwise factor comparisons to score at each level, and Table 6 is the guide for relative importance in comparison. Table 3E is the result of data collection in the form of a matrix.

In phase 2, a priority vector is defined. Denote the normalized vector as $\hat{a}_{ij}^{r} = \frac{a_{ij}^{r}}{\sum_{i=1}^{I} a_{ij}^{r}}$ $(j = 1,2, \dots ,.J)$. The priority is defined as $p_i^r = \frac{\sum_{j=1}^{J} \hat{a}_{ij}^{r}}{J}$.

In phase 3, the CI and CR values are estimated. Figure 2 is the Hypothesized framework of the triage decision as proposed in this research. It defines as Multi-Factor Triage Algorithm (MUFTA). The positive reciprocal matrices (Table 7) are the expert evaluators' data entry results of pairwise comparisons of factors. This matrix finds the eigenvector and eigenvalue. The consistency ratio measures consistency in data entry by pairwise factor judgments. If the magnitude of the consistency index (CI >0.1) is high, the decision is inconsistent, and reevaluation is deemed necessary. Thus, it is a measure of the reliability of the study.

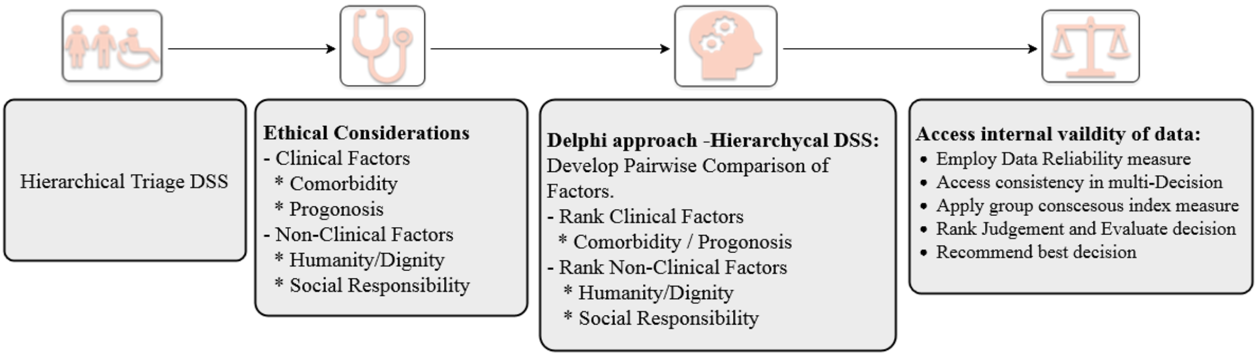

Figure 2. Hypothesized framework of the triage decision Multi-Factor Triage Algorithm, (MUFTA)

In the fourth stage, the algorithm evaluates the alternative decisions. Ultimately, the algorithm either recomputes the priority of the ethical factors under consideration or the relative importance of the weighted average score among the expert opinion is found. The highly ranked patient is the one who needs more attention than others.

7-1- Assessment Criteria

The experts receive patient information without the identity of the patient. The six predetermined factors built into the software during the evaluation process are provided to doctors for expert opinions to compute factor scores. Table 4 is the exhibit of the data gathering process. In the second phase, the factors attribute for the six identified criteria with the patient cases (Case 1, 2, 3, and 4) are evaluated with the guided input of the experts assisted by the software. First, consider each patient's case. Then compare the ethical factors PF1 with PF6 and rank them according to their relative importance. Triage decision is now based on the six criteria related to the four patients. Tables 10 to 13 are the matrix data recorded by the experts.

Table 4 is the decision matrix generated by the MUFTA where expert 1 and expert 2 data are combined and independent evaluation shown. The CR by experts 1 is 7.9% and 6.3%, respectively. The CR is below 10%, implying that the experts' data and opinions are reliable. The pairwise factors comparison evaluates the priority of ethical factors. In other words, it shows how ethical factors are ranked. The scale applied is explained in Table 5 and Table 6. Note that the Expert 1 and Expert 2 data are recorded under columns 1 and 2 as tabulated in row number 2. The corresponding diagonal elements are the inverse value selected by the respondent. The CR for the consolidated score is 2.8%, which is well below the CR critical value of 10%. Furthermore, the “group conscious” ratio is 95.2%, which is above 75%. It implies that data is not much in disagreement or controversy. Compute these values using the Shanon alpha, beta, and gamma entropy.

Figure 3 shows the factor ranking by the experts when all information is combined. Factor 2, which is a non-clinical factor, is ranked high. Figures 3 and 4 are the similar factor scores judged by expert 1 and expert 2 individually. The results are consistent.

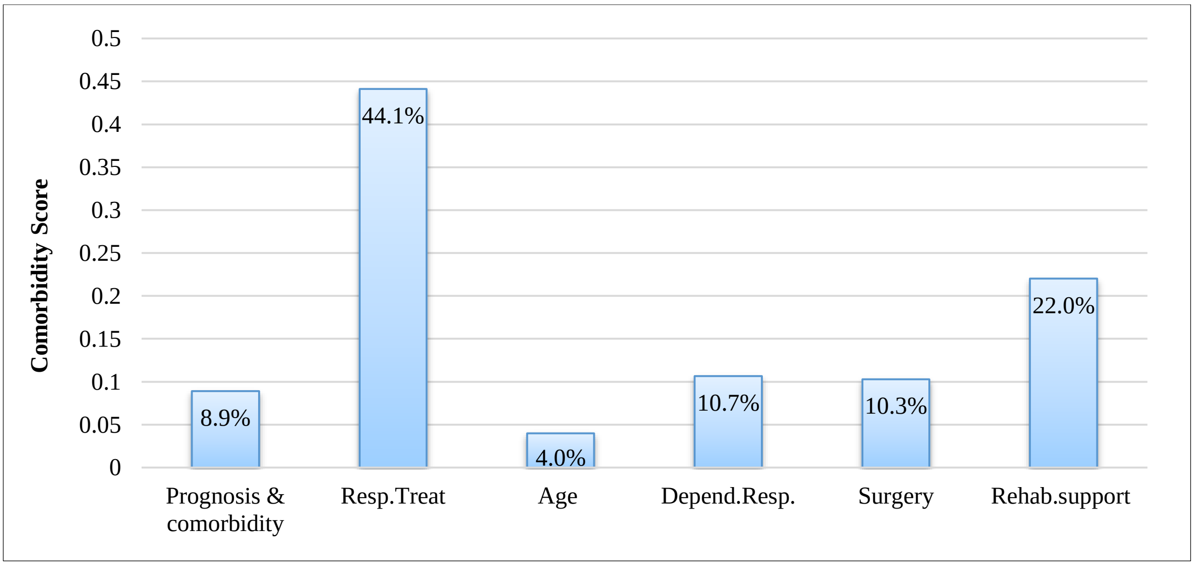

Figure 3. **Expert 1 and 2 Evaluation (Factor Priority)**

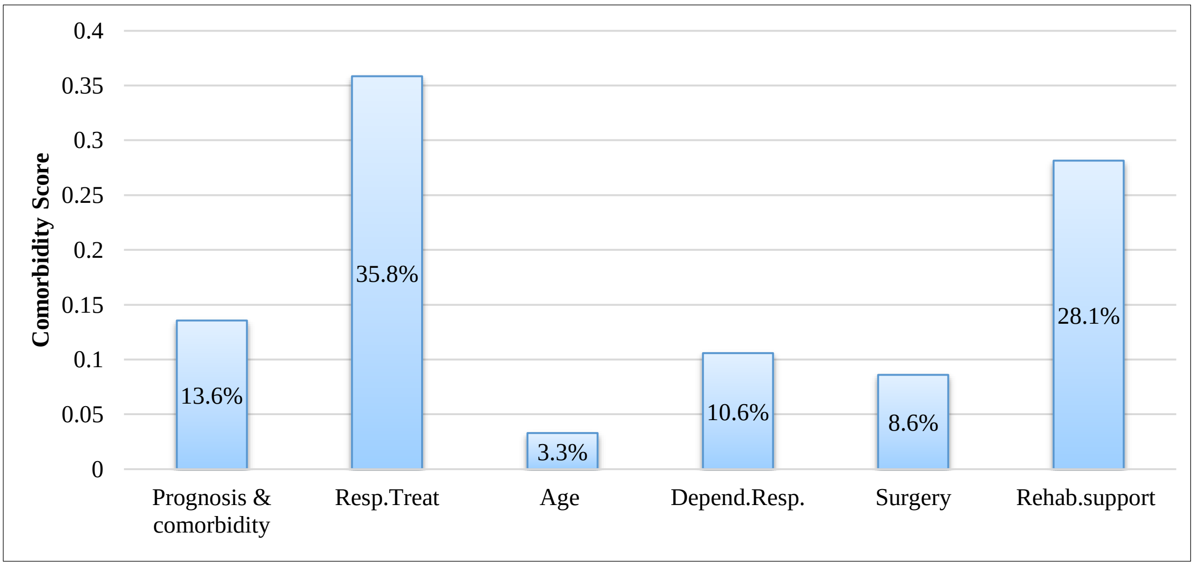

Figure 4. **Expert 1 Evaluation (Factor Priority)**

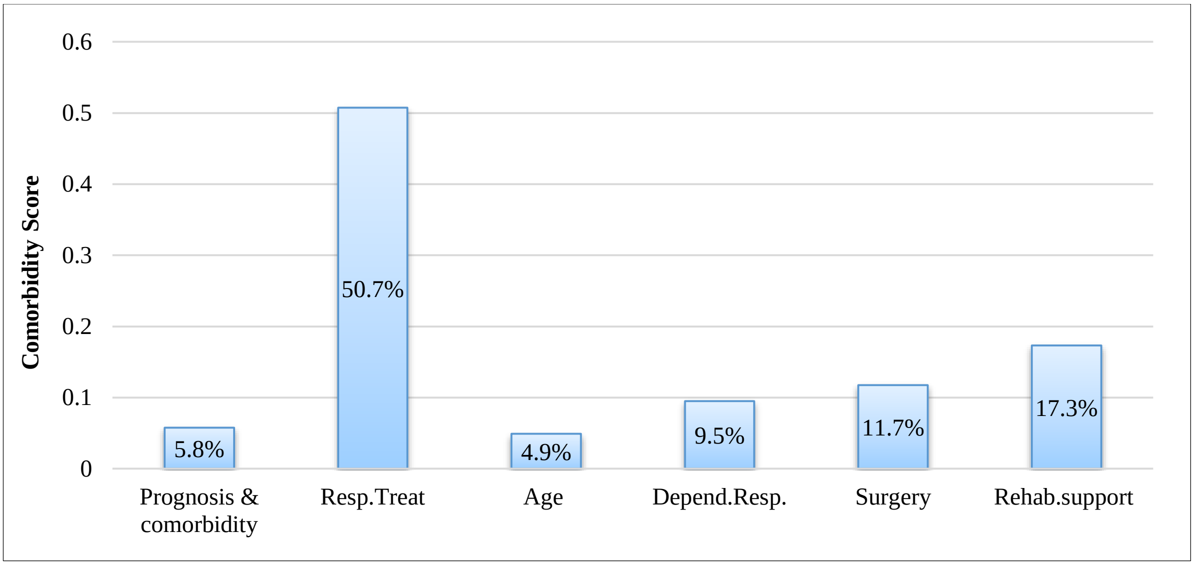

Figure 5. Expert 2 Evaluation (Factor Priority)

Tables 10 to 13 are the decision matrix for patient case 1, 2, 3 and 4 (Table 2). The decisions are recorded by expert 1 and expert 2. The clinical and non-clinical factors (Table 1) are compared pairwise for all the patients by a scale defined in Tables 3, 5, and 6.

Table 10 is the decision matrix generated by the MUFTA when expert 1 and expert 2 data are listed individually. The CR by experts 1 is 9.5% and 8.2%, respectively. In both cases, the CR is below 10%. Therefore, the opinion expressed by the experts is dependable. The pairwise factors are evaluated systematically for patient 1 (Table 10). The reciprocal scale as applied is explained in Table 3A and Table 3D. Note that row number 3 (Table 10) is the listing of the opinion of Expert 1 and Expert 2. Data entries are recorded under columns numbered 1 and 2 as tabulated in row number 3. The corresponding diagonal elements are the inverse value selected by the respondent. The CR for the consolidated score is 6.3%, which is well below the CR critical value of 10%. It implies that data recorded by the experts are in agreement. The maximum eigenvalue computed is 6.197.

The Shanon alpha, beta, and gamma entropies are 4.614, 1.094, and 5.049. The "group conscious" ratio is 80.1% which is above 75%. Therefore, we infer that the data is acceptable. Table 11 to 13 list values for patient cases 2, 3, and 4, respectively.

Applying the MUFTA, all the patient cases and the factors are listed in Table 15. The normalized score is the patient priority. The result is listed in the vector format:

$$[\text{Patient: 1} \quad \text{Patient: 2} \quad \text{Patient: 3} \quad \text{Patient: 4}]^T = [0.281 \quad 0.280 \quad 0.280 \quad 0.158]^T$$

The consolidated score shows that patient cases 1 and 2 are equally ranked. Similarly, the results listed in Table 14 and Table 16 show that all the patients are classified distinctly. Finally, use an equally likelihood expected score to break any tie, as shown in Table 17 and the algorithm finally ranks the patients.

Table 16. Patient Rank with the Multi-Factor Triage Algorithm, (MUFTA) (Expert 2)

Patient	Respondent 2						
	Prognosis & comorbidity	**Resp.Treat**	**Age**	**Depend.Resp.**	**Surgery**	**Rehab.support**	**Normalized Rank**
Case: 1	0.161	0.035	0.093	0.387	0.095	0.229	0.298
Case: 2	0.115	0.057	0.251	0.072	0.066	0.439	0.213
Case: 3	0.163	0.060	0.086	0.251	0.081	0.359	0.300
Case: 4	0.102	0.083	0.364	0.046	0.049	0.356	0.189

Table 17. Patient Rank with the multicriteria decision support system

Patient	Expert			Rank			Combined Rank	Average Score	Rank
Case	1&2	1	2	1&2	1	2	1&2, 1, 2	Equally Weighted	Patient
Case: 1	0.281	0.181	0.298	1	3	2	Undecided	0.254	3
Case: 2	0.280	0.326	0.213	2	2	3	2	0.273	2
Case: 3	0.280	0.356	0.300	2	1	1	1	0.312	1
Case: 4	0.158	0.137	0.189	4	4	4	4	0.161	4

Table 17 is the experts' rank of patients' issues individually and as a consolidated score. The analysis shows that patient case 1 is undecided as no clear ranking emerged. To break the tie, an average score is determined. The decision of the experts individually and combined are weighted equally. The average score provides a clear ranking as listed below:

$[\text{Patient: 1} \quad \text{Patient: 2} \quad \text{Patient: 3} \quad \text{Patient: 4}]^T = [0.254 \quad 0.273 \quad 0.312 \quad 0.161]^T$

$[\text{Patient: 1} \quad \text{Patient: 2} \quad \text{Patient: 3} \quad \text{Patient: 4}]^T = [3 \quad 2 \quad 1 \quad 4]^T.$

The triage result shows that patient case 3 scores high as 1 implies top priority.

7-2- Discussion

Three primary phases are necessary for the algorithm to evaluate. In phase 1, all the ethical factors are prioritized, followed by each patient evaluation against the selected ethical aspects. Finally, the patients are ranked as per the triage scores in the final step. First, the algorithm's power is the measurement of consistency ratio that demonstrates the reliability measurements for clinical and non-clinical ethical factors. Consequently, it implies that all experts recorded a homogeneous response for a patient competing for ICU equipment and its ranking. Second, Table 1 is an essential factor in prioritization data to rank patients. Finally, priorities of ethical aspects and patient conditions provide a meaningful ranking order of patients.

In the case of patient 1, the hierarchical assessment posed a problem. From Table 10, we see the group consensus ratio was 80.1%, and the score exceeded 75%, but this perhaps created a dilemma. It suggests that experts' opinions are different. A value above 90% is probably better. In this case, a review of the score is possible as long as time and resources allow; otherwise, it can be remedied in the same way as shown in Table 17. A tiebreak between the expert opinion classifies a patient's rank. As COVID-19 continues, the need for rapid classification under critical conditions [54] is a crucial tool with a software evaluation.

The suggested algorithm (MUFTA) is suitable for various triage factors for clinical ethical decisions. The triage algorithm is flexible in applying different criteria and evaluating triage decisions. It estimates scores with the help of expert opinions and their experiences. We analyze the responses of two selected experts as shown in Tables 4 and 10 to 13 and Figures 3 to 5. The expert opinion of the two judges sets the priority of the six comparative criteria. As the analysis shows, the consensus of respondents is reliable and consistent. Data on complications for the four patients are processed to determine patient rankings. Experts use a comparative scale shown in Table 6 to record instantaneous morbidity information by comparing two assigned factors. Pairwise comparison of ethical factors forms a matrix leading to data collection (Tables 3 and 4). The matrix contains input data on ethical aspects, both social and medical, to create a priority vector. Then, the software generates a questionnaire to collect the data. Figures 1 and 2 are the conceptual framework of evaluation.MUFTA offers options for determining each criterion and patient rating (Tables 14, 16, and 17).

This algorithm allows decision-makers to find cognitive biases that can influence judgments. This process is a transparent decision-making process. This methodology is efficient in structuring problems in decision-making frameworks. However, if the decision is multifaceted, the comparison process can be slow due to reassignment of priority. The clarity in policymaking is at a disadvantage to business owners interested in manipulating results. Group decision-making can make it difficult for the Delphi process to handle consistency without professional multi-skilled facilitation. A minimum of two experts in the medical field is necessary to evaluate the triage decision and an experienced triage matron as a moderator. A committee of five involving one representative of patients and a senior hospital administrator is recommended for the triage review and debriefing committee.

Algorithms using quantitative and qualitative methods for COVID-19 triage are rare in literature. The algorithm reported in WHO (WPR/DSE/2020/009) [55] aims to give overall guidance for the triage and referral of symptomatic COVID-19 patients. This triage SOP is in the context of the COVID-19 pandemic. It does not replace routine clinical triage SOPs in place in healthcare facilities. In contrast, the algorithm [56] provides a general framework for local health systems, ministries of health, hospital administrators, and health workers working on planning COVID-19 patient triage, management, and referral. Jänig et al. [57] presented SAINT for the Intensive Care Unit Triage algorithm. It is an approach that fits the specific entities that determine the framework of the particular military health system abroad. Turcato et al. [58] evaluate the inclusion of pre-triage during the COVID-19 outbreak at Merano General Hospital in Italy. They implement a pre-triage protocol to divide patients based on their risk of infection. Pre-triage performance is measured in sensitivity, specificity, and negative predictive value. All patients who require an emergency department visit are admitted to triage to distinguish between immediate care and those who can safely wait. This algorithm, however, is insufficient to account for a variety of ethical factors.

The triage algorithms available in the literature are specific in context, and the presented algorithm is global rather than limited in application or regional.

8- Conclusion

The presented triage algorithm is a tool for health care professionals to simplify the challenging task of triaging. The team leader is responsible for the triage decisions. The proposed algorithm will help reduce stress and relieve the individual's decision-making risk, ethical judgment, critical medical needs, and admission policies in the emergency section. This study shows multiple ethical criteria evaluations that lead to patient screening and ranking. The algorithm is flexible enough to accommodate various bio-ethical and social factors. The advantage of decision-making algorithms is that the measurement of the evaluation process identifies inconsistencies, if any. The pairwise comparison essentially constructs a matrix in the form of coherence and group consciousness ratios. A high percentage of consistency represents an inconsistent evaluation or measurement process. A good consistency ratio is less than 10%. In some cases, consistency ratios of over 10% are accepted [52]. The reliability of data collection and the internal consistency of data analysis are strong when the triage decision has a “CR” of less than 10%. This may suggest that data collection and evaluation are consistent [59].

Data collection reliability for triage decisions is inconsistent and nonrobust if the “CR”> 10%. Therefore, if the “CR” exceeds 10%, the irregularity of judgment is determined. The “group-conscious ratio” value above 90% should have an overall unbiased assessment in the ranking process. A low metric allows the Delphi team to review the evaluation process during the data entry phase. The software supports this procedure, so one can quickly and easily see all the metrics for a better ranking process. This algorithm shows how classification decisions are made based on several ethical factors.

The proposed algorithm can distinguish between minor, severe, and risky conditions in infected patients. It results in patients' fair ranking and placement because of the number of patients infected with COVID-19 or its variants. However, due to the inability to provide services to all patients, the patient triage guidelines are under tremendous pressure. Therefore, if circumstances permit, it is urgent to expand the facility with military logistics cooperation. Furthermore, the government's CAPEX budget should release emergency investment funds to support the spread of national disasters. The reason for this recommendation is that all lives are equal. In an accident, the health care system needs support to help patients in need and protect human dignity. In this case, the rule of Utilitarianism applies. Therefore, experts, policymakers, hospital managers, and stakeholders can benefit from the proposed method.

This study has limitations if the patient’s comorbidity history is unavailable for scoring systems. In this case, the score depends on the patient’s responses and the understanding of the triaging officer. The quality and statistics of the patient data will significantly influence the triage score. Here, the triage score may require validation before arriving at a decision. COVID-19 and its variants, including Omicron, have high variability of infection and transmission from one individual to another. The microbiology of the disease is not yet thoroughly studied for the several variants that appear in the human body with different clinical symptoms. Therefore, there will likely be some degree of misjudgment in the triage score.

9- Declarations

9-1- Author Contributions

Conceptualization, S.A.; methodology, S.A.; validation, S.A.; formal analysis, S.A.; investigation, S.A., and R.A.S.; resources, S.A., and R.A.S.; data curation, S.A.; writing—original draft preparation, S.A.; writing—review and editing, S.A.; visualization, S.A., and R.S.A.; supervision, S.A., and R.S.A; project administration, S.A.; funding acquisition, S.A. All authors have read and agreed to the published version of the manuscript.

9-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

9-3- Funding

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9-5- Institutional Review Board Statement

The study confirms the ethical guidelines of the “Declaration of Helsinki” and the research priority approved by the scientific research committee of the Faculty of Engineering at the Islamic University of Madinah (2020).

9-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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