Decision Analysis of the COVID-19 Vaccines

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Abstract

The entire globe is struggling with the COVID-19 pandemic since March 11, 2020. There is still a large number of infected patients and death, and there is no proven treatment for the infection yet. This has led to the race in vaccine development to protect people from COVID-19 infection. As of February 3, 2021, there were 289 experimental COVID -19 vaccines in development, 66 of which were in clinical trials with different phases, and 20 of them were in phase 3.

This study aims to evaluate 15 important vaccines based on criteria such as the dose number, dosing schedule, storage advantages, efficacy, and side effect. In this evaluation, we use the fuzzy PROMETHEE approach, which is an important Multi-Criteria Decision Making (MCDM) technique. The importance level of the criteria is determined based on expert opinion. The result shows that the EpiVacCorona vaccine is the most effective vaccine to prevent COVID-19 infections based on the selected criteria and the importance level of each criterion.

The result obtained may change based on individual or expert's priorities. Due to the use of different criteria for the ranking and different weightings of the criteria, the ranking result may differ. This study also shows the strengths and weaknesses of the selected vaccines and the applicability of the MCDM technique for the evaluation of COVID -19 vaccines.

Keyword: COVID-19; MCDM; Pandemic; PROMETHEE; Vaccine.

Introduction

Coronaviruses are enveloped viruses that contain a positive-sense single-stranded Ribonucleic acid (RNA) genome and a helical symmetry nucleocapsid. It is among the largest RNA viruses with a genomes range of about 26-32 kilobases (1). They have a distinctive crown appearance when viewed under the microscope from which they got their name (2). Some kind of coronavirus causes common diseases among humans. This ranges from the common cold to mild or moderate respiratory illnesses (3). Other kinds of coronaviruses affect animals and on rare occasions jump from animal species into the human population (4). The novel coronavirus (COVID-19) infection caused by Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) (5, 6) was declared a pandemic by the World Health Organization (WHO) on the 11th March 2020 (7). This was as a result of its uncontrollable spread throughout the continent. As of 24th April 2021, about 145,672,293 confirmed cases (8) and 3,087,046 COVID-19 related deaths (9) were recorded. Recent studies indicate that the Wuhan strain which is genetically similar to the SARS-CoV is a new strain of Betacoronavirus from group 2B (10). Also, because of the high percentage of similarity (about 96%) of SARS-CoV-2 and bat coronavirus, SARS-CoV-2 is widely believed to have originated from bat (11, 12). People react differently to coronavirus infection (13). Some show common symptoms such as fever, dry cough and tiredness while others exhibit less common symptoms such as aches and pains, sore throat, diarrhoea, conjunctivitis, headache, loss of taste or smell, and discoloration of fingers and toes (13). In serious cases, symptoms such as difficulty in breathing and shortness of breath are common. This is often followed by chest pain, loss of speech and more (13).

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Since the emergence of the COVID-19 pandemic in early 2020, the global economy and food security have been threatened to a record low, while the mental health of the global population has been greatly impacted. There has been an increase in job loss, deprivation of education and a decline in the overall welfare of people. For the world to get back to normal, it is fundamental that the spread of the disease is contained. Hence, the use of face mask, self-isolation, avoiding crowded and vaccination is encouraged. Among the aforementioned preventive measures, vaccination remains the most effective as it does not only reduce mortality but also the spread rate (14). Several pharmaceutical companies and research institute have come up with vaccines capable of reducing transmission and death. However, some vaccines prove to be ineffective against certain variant/strain of the virus. A novel SARS-CoV-2 strain possesses one or more mutations that distinguish it from the virus variants that are already prevalent in the general population. Variants differ, as viruses are continually evolving (15). Surveillance may aid in the investigation of how certain variants can affect the transmission or severity of COVID-19 disease, as well as the efficacy of vaccines and therapeutics.

The human COVID-19 vaccines are further classified into two major groups namely; Virus-based and Protein-based vaccines (16). The concept used in the human-based approach includes Purified proteins from viruses, virus-infected cells, recombinant proteins, and virus-like particles (VLP) (16). VLPs are structural protein fragments that can form a virus fragment but do not carry a viral genome. In these vaccines, adjuvants are used to create a strong immune response. Adjuvants are added to stimulate the immune system stronger (16). Virus based vaccines can either be inactive and live-attenuated vaccines. The virus in Live-Attenuated vaccines is introduced into a cell culture until it becomes disease-free (16). It is injected into the human host to elicit immunity thereby causing a very mild reaction.

Materials and Methods

PROMETHEE

The Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) is one of the best multiple criteria decision-making tool available which allows users to effectively evaluate and rank alternatives based on certain criteria (17). The ranking will eventually produce a desirable ranking from the most preferred alternative to the least preferred alternative. When compared with other Multi-Criteria Decision Making (MCDM) method, PROMETHEE differs by its capability to enable the decision-maker to use different types of preference functions for each criterion (17). PROMETHEE can simultaneously analyze quantitative and qualitative data. It can also deal with fuzzy relations, vagueness and uncertainties of the data, and give users maximum control over the weights of the criteria (17). Applying PROMETHEE to a real-life scenario is easy and straightforward. Decision-makers only need to assign an appropriate weight and preference function to every criterion selected (18). The weight highlights the importance of each criterion to the alternative and it ranges from 0-1 (17). The higher

the importance, the higher the weight assigned. The preference function indicates the difference of alternatives based on a specific criterion. Both the weighting and the preference function can be set by the user based on various circumstances (17).

To effectively evaluate vaccines based on specific criteria, a triangular fuzzy linguistic scale of importance is used as shown in Table 1. This linguistic scale indicates the significance of each criterion. Using the Yager index the fuzzy values of the linguistic scale has been defuzzified. After collecting the necessary data as shown in Table 2, the Gaussian preference function was utilized for each criterion.

As of February 3, 2021, there were 289 experimental COVID-19 vaccines in development, 66 of which were in different phases of the clinical trial, including 20 in phase 3 (19). Our study is aimed towards evaluating fifteen (15) vaccines based on the criteria namely; dose number, dosing schedule, storage temperature, efficacy, and side effect using fuzzy-based MCDM technique. This will help decision-maker in the selection process and administration of safe vaccines for the population at large. This technique's main advantages include; its user-friendliness, completeness of ranking, and applications to real-life planning problems (20).

The number of dosage required for full immunity plays an important role in the selection of vaccines. It is believed that people often prefer a single dose of the vaccine rather than receiving the vaccination twice. This will prevent a possible inflammation at the site of injection. In a situation where a double vaccination is imminent, the majority of the population will prefer to receive the second dose within a short period so they can go back to their life without the fear of getting infected with the coronavirus. There are groups of people with great fear for any medical procedure which involves needle injection into the body, hence, can be considerably impacted by COVID-19 vaccination. In some cases, they may decide not to be vaccinated. Also, needle injection through the intramuscular route is preferable to the intradermal route (21). This will make intramuscular vaccines more acceptable when compared with the intradermal route. Other criteria such as storage advantages, efficacy, side-effect and medical emergency authorization play an important role in choosing a vaccine. Vaccines with a very low storage temperature will cause serious logistic problems and improper storage of the vaccine will render it ineffective. An adverse side-effect is a major factor in vaccine production. The primary goal of a vaccine is to protect the body from a disease with little or no side effect (22). Any vaccine with a considerably serious side effect will jeopardize its usefulness and render its fatal.

According to our study, EpiVacCorona is the most preferred COVID-19 vaccine while Covishield is the least preferred alternative. EpiVacCorona is a COVID-19 preventive vaccine developed by the Vektor State Research Center of Virology and Biotechnology in Russia (23). EpiVacCorona is an antigens-based vaccine that provokes an immune reaction against COVID-19 and promotes the further development of immunity. It is administered via the intramuscular route as two dosages with a

Table 1. The linguistic fuzzy scale and the selected importance levels

Linguistic scale	Triangular fuzzy scale	Criteria
Very High (VH)	0.75, 1, 1	Efficacy
High (H)	0.5, 0.75, 1	Side Effects
Medium (M)	0.25, 0.5, 0.75	Logistic advantages
Low (L)	0, 0.25, 0.5	Dose Number, Dosing schedule
Very Low (VL)	0, 0, 0.25	-

Table 2. Visual PROMETHEE application for Vaccine selection

Criteria	Dose Number	Dosing Schedule	Storage Advantages	Efficacy	Side Effects
Aim (Max/Min)					
	Min	Min	Max	Max	Min
Evaluation					
Pfizer/Biontech	2	L	No	95	VH
Moderna	2	M	No	94.5	M
CanSino Biologics	1	M	Yes	66	M
Sputnik V	2	L	No	95	VL
EpiVacCorona	2	M	Yes	100	VL
Sinopharm (BBIBP-CorV)	2	L	Yes	79	H
Sinopharm (WIBP-CorV)	2	L	Yes	79	H
CoronaVac	2	M	Yes	83.5	M
Oxford/AstraZeneca	2	M	Yes	82	H
Novavax	2	L	Yes	89.3	M
Johnson & Johnson vaccine (Janssen Pharmaceutical)	1	H	Yes	72	M
Inovio Pharmaceuticals + International Vaccine Institute	2	M	No	95	H
Covaxin (Bharat Biotech)	2	M	No	81	H
Medicago/GSK vaccine candidate	2	L	No	95	M
Covishield (Pune-based Serum Institute of India (SII))	2	L	No	62	M

Abbreviations: Very High (VH), High (H), Medium (M), Low (L), Very Low (VL)

time range of 21 to 28 days (24). EpiVacCorona with a net flow of 0.3242 as shown in Table 3 outperformed all other alternatives. It has an efficacy of 100% and a very low side effect. This contributes to its outstanding performance when compared with other alternatives. Covishield is made from a weakened version of a common cold virus (known as an adenovirus) from chimpanzees (25). It has been modified to look more like coronavirus, although it can't cause illness. The vaccination is administered in two doses between four and 12 weeks and can be stored between 2°C to 8°C (25).

Covishield has a net outranking flow of -0.3408 and a positive and negative outranking flow of 0.0006 and 0.3414 respectively. The ranking of other alternative is presented in Table 3. Sputnik V ranked second. It is a 2 dose vaccine manufactured by the Gamaleya Research Institute, part of Russia's Ministry of

Health. It has an efficacy rate of 95% and has received emergency use approval in Russia and dozens of other countries (26). It ranked second with a net flow of 0.1977. Pfizer/Biontech and Moderna vaccines which ranked 5th and 6th respectively are mRNA vaccines that are 95% and 94.5% effective at preventing laboratory-confirmed COVID-19 illness in people without evidence of previous infection. They are both manufactured in the United State of America (USA) by Pfizer Inc. and BioNTech and Moderna pharmaceutical company respectively. Both vaccines have been approved by the Food and Drug Administration (FDA) in the USA for emergency use (27). Johnson & Johnson vaccine ranked 13th. It is a viral vaccine produced by Janssen Pharmaceuticals Companies of Johnson & Johnson in the USA. It is a one-dose vaccine with 72% effectiveness in clinical trials at preventing laboratory-confirmed COVID-19

Table 3. A complete ranking of COVID-19 Vaccines

Ranking	Vaccines	Net Flow	Positive outranking flow	Negative outranking flow
1	EpiVacCorona	0.3242	0.3251	0.0009
2	Sputnik V	0.1977	0.2227	0.0250
3	Medicago/GSK vaccine candidate	0.1932	0.2186	0.0254
4	Inovio Pharmaceuticals + International Vaccine Institute	0.1912	0.2178	0.0266
5	Pfizer/Biontech	0.1900	0.2181	0.281
6	Moderna	0.1881	0.2166	0.0284
7	Novavax	0.0700	0.1970	0.1271
8	Sinovac/CoronaVac	-0.0468	0.1228	0.1696
9	Oxford / AstraZeneca	-0.0767	0.0996	0.1762
10	Covaxin (Bharat Biotech)	-0.1050	0.0834	0.1884
11	Sinopharm (BBIBP-CorV)	-0.1280	0.0776	0.2056
11	Sinopharm (WIBP-CorV) (Janssen Pharmaceutical)	-0.1280	0.0776	0.2056
13	Johnson & Johnson vaccine	-0.2368	0.0561	0.2929
14	CanSino Biologics Inc.	-0.2923	0.0248	0.3172
15	Covishield (Pune-based Serum Institute of India (SII))	-0.3408	0.0006	0.3414

illness in people who had no evidence of prior infection 2 weeks after receiving the vaccine (28).

CanSino Biologics Inc.'s experimental coronavirus vaccine is also a one-dose vaccine with an efficacy rate of 65.7% at preventing symptomatic cases. Cansino is the first non-replicating adenovirus type-5 (Ad5) vectored COVID-19 vaccine to be approved in China (29). The vaccine has an efficacy of 90.07% at preventing severe disease after 28 days following a single dose. According to our study, it ranked 14th in preventing COVID-19. The Sinopharm vaccine is suitable for the prevention of the disease (COVID-19) caused by the new coronavirus infection. It is a single short vaccine approved for emergency use in China and several other countries. In April 2020, China approved clinical trials for a candidate COVID-19 vaccine developed by Sinopharm's Beijing Institute of Biological Products (BBIBP-CorV) (29) and the Wuhan Institute of Biological Products (WIBP-CorV) (30). Both vaccines are chemically-inactive whole virus vaccines for COVID-19 and ranked 11th and 11th with an equal net flow of -0.1280. Sinovac/CoronaVac is a COVID-19 vaccine (inactivated virus) developed by the Chinese company Sinovac Biotech. A real-world study of millions of Chileans who received CoronaVac found it 67% effective against symptoms, reduced hospitalizations by 85%, intensive care visits by 89%, and deaths by 80% (31).

Sinovac/CoronaVac ranked 8th with a net flow of -0.0468. Oxford/AstraZeneca, Novavax, Janssen Pharmaceutical, Inovio Pharma. + International Vaccine Ins, Bharat Biotech, Medicago/GSK, and Pune-based Serum Institute of India (SII) are the other vaccines considered for the study. These vaccines are recommended to be injected into the muscle of the upper arm (27) with notable side effects such as tiredness, headache, muscle pain, chills, fever and nausea.

Conclusion

The study concludes that the EpiVacCorona vaccine is the best COVID -19 vaccine due to its high efficacy and very low side effect. The use of fuzzy MCDM technique, fuzzy PROMETHEE, simplifies the decision maker's confusion in selecting safe vaccines for human use. This study shows the strengths and weaknesses of the selected vaccines, which could also be very important and beneficial for the users and for the experts, working in this field. The study was able to show the applicability of the fuzzy PROMETHEE technique in vaccine selection. This study can be improved by including other vaccines and additional criteria based on individual priorities.

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