A Survey for Promising COVID-19 Vaccines: Issues, Advantages, and new Research Directions

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Abstract

The world population facing the outbreak of a dangerous epidemic namely COVID-19 nowadays. This epidemic is considered one of the most dangerous diseases that have spread in this century. The World Health Organization (WHO) has called on all health care sectors and research laboratories to produce an appropriate vaccine to confront this epidemic around the world. Nevertheless, many specialized medical research centers have produced vaccines according to certain criteria in many advanced countries. Many of these vaccines have been approved to vaccinate the infected and the uninfected to counteract the variants versions of this epidemic. Some of these vaccines are showed efficacy against different variants, especially the delta variant. The paper aims to present a survey of the best types of approved vaccines and highlight their advantages and disadvantages and new promising directions. This survey highlighted the top ten vaccines produced and approved globally, to help countries choose the best one according to their characteristics. Therefore, we call people to take the vaccination against this dangerous epidemic to control and prevent its spread.

Keywords: COVID-19 vaccines, WHO, Epidemic, Criteria, Survey, MCDM

1. Introduction

About a year ago, the dangerous coronavirus spread, and its effects still remain now. The virus first appeared in China, the city of Wuhan, in December 2019. The World Health Organization has launched a distress call to all countries to take action to confront this deadly epidemic [1] [2]. According to the reports by WHO on 7 July and June 2020, about 139 candidate vaccines were proposed in stages of preclinical trials. In contrast, about 21 COVID-19 vaccines are being clinically tested on humans to prevent coronavirus[3]. In this study, the top ten vaccines actually used around the world will be highlighted that have completed phase III of its clinical trials. Four main platforms to develop candidate COVID-19 vaccines have been used.

First in this category of vaccine development platforms that depend on the use of inactivated or isolated viruses, and it is considered one of the traditional methods of vaccination that was previously applied. This platform includes three basic vaccines: Sinopharm or (BBIBP-CorV), Sinovac Institutes have received final approval from the World Health Organization and the Chinese National Medical Products Administration (NMPA), and India's Bharat Biotech vaccine[4]. Second, this class of platforms is called viral vectors which are designed to transfer coronavirus genes via viral vectors into the cells of the body. The mechanism of this vaccine depends on injecting the coronavirus protein across the cell membrane to activate the body's immune system using the replication process. This platform included three main vaccines that obtained approval by WHO to use globally as Oxford-AstraZeneca (ChAdOx1 nCoV-19) in UK, Johnson & Johnson vaccine in the USA, and Gam-COVID-Vac vaccine (Sputnik V) in Russia [5]. Third, this class of Spike protein-based vaccine platform was synthesized using recombinant nanoparticle technology with a saponin-containing Matrix-M matrix. The platform included a vaccine called Novavax which is produced by a US biotechnology company and has been approved for use globally[6]. Finally, the category of vaccine development platforms against COVID-19 is based on messenger RNA (mRNA), which activates the body's immune response to create immunity to the virus. This type of vaccine relies on how messenger RNA works by sending instructions to the cell and making a piece of the "spike protein" in the SARS-CoV-2 coronavirus. The platform includes three main vaccines that have received final approval for widespread use as Moderna vaccine, Pfizer-BioNTech vaccine produced in the USA, and CanSino Biological in China [7].

These vaccines showed varying resistance against the variants of the coronavirus. However, after the outbreak of the emerging coronavirus at the beginning of 2020, various copies of this variant appeared in many countries. For example, the alpha variant in the United Kingdom, the beta variant in South Africa, the gamma variant in Brazil, and the delta variant in India which the most dangerous and highly contagious among humans. Therefore, vaccines must be able to respond to these mutations, especially the delta variant. [8].

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Despite the rapid spread of the epidemic coronavirus, so the best solution is to start vaccinating health care workers as a top priority because they are the closest to infection. At the end of 2021 is expected, vaccines will be available to all populations of the world. Therefore, the speed of conducting clinical trials on volunteers results in the discovery of appropriate and effective vaccines to confront the spread of the epidemic among people [9]. The survey highlighted different platforms for developing vaccines against COVID-19 such as RNA, DNA, non-recurrent viral vectors, and inactivated vaccines, through which the efficacy of these vaccines can be evaluated. [10].

The survey aims to discuss strategies for developing safe, effective, and widespread use of vaccines to prevent COVID-19 infection. An in-depth analysis of various researches was conducted on the development of several vaccines against COVID-19. This study provided new insight into the development of potential vaccines against the emerging virus, by presenting a new idea to reduce the period of vaccine development[3].

Overview of COVID-19 vaccines platforms

Since the beginning of the spread of the coronavirus epidemic around the world, many medical and drug research centers have begun to find a suitable vaccine for the disease. Several vaccines have been proposed within several platforms. Several candidate vaccine platforms are discussed; protein-based virus, live inactivated or attenuated virus, virus-like particles, DNA-based vectors, and viral vectors[11],[12], [13]. Since the coronavirus outbreak a year ago and the emergence of mutants for the disease, several vaccines, and antiviral products are still under development within advanced clinical trials in many countries[14], [11],[15]. Figure 1, shows the taxonomy included various platforms of COVID-19 vaccines.

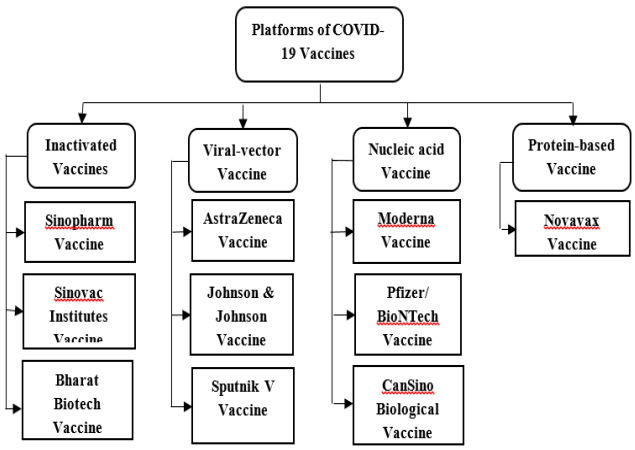

Figure 1, Taxonomy of COVID-19 vaccines platforms

Inactivated vaccines

Basically, inactivated vaccines contain the form of a pathogen that has no ability to produce disease. Therefore, during viral replication, purification and concentration are often carried out before the inactivation of the vaccine [16]. Most of the licensed antiviral vaccines use formaldehyde and betapropiolactone to inactivate the virus [17]. Inactivated vaccines often require the use of multiple doses or adjuvants to be most effective [18]. Wuhan Institute of Biological Products/Sinopharm, Beijing Institute of Biological Products/Sinopharm, and Sinovac Institutes have developed the inactivated platform. All of them have conducted clinical phase III trials for the candidate vaccines. The type of candidate vaccine containing inactivated aluminum was provided by the Wuhan Institute and Sinovac. The nature of the antigen used in this vaccine is a complete virus by the three institutes that were produced, while only the Wuhan Institute provided a multiple-dose vaccine. The Wuhan vaccine has a more humoral invulnerable response, while the Sinovac Institute vaccine has a mostly humoral invulnerable response, which is increased the existence of aluminum adjuvant in the vaccine [19],[20]. The next section highlights the advantages and disadvantages aspects of approved vaccines.

Sinopharm: Sinopharm's group produced a vaccine called BBIBP-CorV at the government Beijing Institute in cooperation with the Center for Disease Control and Prevention. On December 31, 2021, the Chinese National Medical Products Administration (NMPA) approved this vaccine, and the World Health Organization provided the emergency use authorization on May 7, 2021, after conducting phase III trials to be used globally later [21],[22].

Advantages

This vaccine was given in two doses, with a third booster dose being given later [23],[24]. The percentage of this vaccine efficacy was recorded between (79.4% and 72.5%) in most of the countries vaccinated according to interim results [22]. The trials of the Sinopharm vaccine showed is safe and high capacity tolerated, as well it recorded a 100% humoral immune response during vaccination of people. The appropriate temperature to save the vaccine at 2 to 8 C° (36 F to 46 F) is similar to a normal refrigerator temperature compared to other vaccines that require very low temperatures [24],[25]. On the other hand, this vaccine provides protection and reduces infections among people after taking the vaccine [23]. Therefore, the main advantage of this vaccine is the use of an inactive virus that contains a non-living disease pathogen, so it does not cause any harm to the patient during repeated infection [19],[20]. The development of the Sinopharm vaccine is ongoing by Chinese drug makers against the Covid-19 pandemic to protect from variants of the beta and delta highly contagious. As well as, testing a third booster dose or combination techniques to enhance immunity [21].

Disadvantages

The main side effects of the vaccine that have been reported, such as headache, fever, sickness,

tiredness, dizziness, vomiting, and skin sensitivity. [26],[24]. Despite the new features provided by this vaccine, it does not prevent infection for vaccinated people [23].

Sinovac Institutes: This vaccine is considered in the category of inactivated vaccines, as it uses viruses, as it uses a killed virus The manufacturer of the Sinovac Biotech COVID-19 vaccine announced the start of its widely used in china after approval on Feb 2021, and it showed significant efficacy in recent clinical trials [27].

Advantages

This vaccine is characterized by a humoral immune response, which helps the presence of adjuvant aluminum [23],[24]. The Sinovac vaccine provided partial or complete protection against COVID-19 with two doses for 14 days at (3 and 6 μg) [28],[29]. Sinovac vaccine recorded varying efficacy among (50.38% to 91.25%), which meet the requirements of the WHO depending on the clinical trials [30]. All Chinese production of vaccines is typically saved at room temperature degrees almost 2 to 8 Co [29]. According to the literature, this vaccine has been shown a highly effective against virus mutants such as alpha, beta-kappa, and gamma but does not show efficacy against the delta variant [31].

Disadvantages

According to the literature, this vaccine is completely safe and has not shown significant side effects from taking the vaccine. As well, the rate of its immune response to the body was high through the formation of antibodies to the vaccinated. Therefore, the side effects of this vaccine are considered mild to moderate and can be recovered later [30].

Bharat Biotech: The Indian Company Bharat Biotech announced the production of its vaccine on July 9, 2021, which received the approval of the World Health Organization (WHO) and inclusion in the Emergency Use List (EUL) after conducting the third clinical trial. This vaccine is currently authorized in more than 13 countries and is considered the most promising vaccine after being tested by volunteers in the healthcare centers [32].

Advantages

This vaccine is characterized by safety, tolerance, reactivity, and a good immune response. It is offered in two doses and has been successfully tested on healthy volunteers, as well as recommended to be taken within a 28-day period [32],[33],[34]. According to the provisional efficacy data against COVID-19 issued by Bharat Biotech on 3 March 2021, it showed an efficacy and safety rate of 81% in previously uninfected subjects [33],[34]. This vaccine does not need a temperature below zero degrees Celsius and does not require reconstruction when stored and is filled in multiple vials, so it can be maintained at a normal temperature of 2-8 C [33],[34]. The Indian company Bharat Biotech confirmed that its vaccine in phase III of clinical trials showed satisfactory efficacy against the novel coronavirus and also provides significant protection of 65.2% against the delta variant [35],[5].

Disadvantages

The top side effects of this vaccine according to the literature can be highlighted. For example, "injection site pain, swelling at the site, redness at the site, itching at the site, stiffness in the upper arm, weakness in the injection arm, body pains, headache, fever, malaise, weakness, inflammation, sickness, vomiting. In contrast, the physicians have recommended to pregnant women and nursing mothers not to take this vaccine during this period [34].

Viral-vector vaccine

Viral vector-based vaccines (VBVs) are produced by utilizing an engineered viral vector that transfers the genes of the infected coronavirus to the infected body to slowly replicate in cells. Thus, the immune system is activated by the production of the coronavirus protein using the replication process [5]. A virus vector vaccine has been genetically developed to express COVID-19 proteins on an external surface. This type of vaccine is commonly used and effective against viruses and provides effective immunity to the body of the vaccinated. [36]. This type of vaccine is commonly used and effective against viruses and provides effective immunity to the body of the vaccinated. Essentially, the vaccine is based on a weak copy of the common cold virus (adenovirus), whose main component is the genetic material of Covid-19 spike protein S. The defense strategy for this vaccine is based on the production of the S protein to resist the virus by generating antibodies that will be provided complete immunity to the body after receiving the vaccine. The greatest advantage of this vaccine is to generate a strong immune response for each dose taken, thus preventing the person from getting infected again after receiving the vaccine. As well, it is safe and tolerant of environmental conditions. While the disadvantages of the vaccine may cause temporary side effects such as a high temperature, headache or arm pain at the injection site [3]. The types of vaccines that depend on the virus vector platform will be discussed as follows

AstraZeneca: The Oxford-AstraZeneca vaccine (ChAdOx1 nCoV-19) is among three vaccines produced in the United Kingdom that have received clearance from the regulatory committee for the prevention of COVID-19, and also getting approval from the WHO for use at the end of March 2021[37]. Basically, this vaccine is based on viral vectors that stimulate the coronavirus protein to activate the body's immune system. [38].

Advantages

AstraZeneca and Oxford University developed this vaccine according to a two-dose system, with a period of time between them about 28 days [39].

The effectiveness of this vaccine was found after taking the two doses for a period of 12 weeks, reaching 82.4%. Whereas, the effectiveness of the vaccine was found at 54.9% if the two doses were taken at an interval of fewer than six weeks [40]. According to the manufacturer's instructions, this vaccine can be stored at a temperature (2 to 8)°C and does not need to be frozen. In addition, the vaccine must be used within six hours after withdrawing it from the vial [41],[29]. Tests in the UK have shown the AstraZeneca vaccine to be highly effective after taking both doses. Also, it has significant efficacy against the delta variant (B.1.617) but is less effective against the alpha variant (B.1.1.7) and the beta variant (B.1.351)[42],[43].

Disadvantages

This vaccine has several side effects that appear on the recipients of the vaccine. The most notable side effects reported for this vaccine such as queasiness, flu-like symptoms, high temperature, extreme sweating, inflated lymph nodes, pain, lack of appetite, and confusion. In addition, a case of hemiplegia in the right hand, and clots in the venous sinuses were recorded after taking the vaccine [44],[26].

Johnson & Johnson: The Johnson & Johnson vaccine is a part of the viral vectors platform that uses adenovirus type 26 as the like Russian vaccine called Sputnik V [p2-vac2-3]. Johnson & Johnson company announced on 27 February 2021, that its vaccine has obtained final authorization by the US Food and Drug Administration (FDA) has issued an Emergency Use Authorization (EUA) according to a single-dose system, to prevent COVID-19 for people 18 years of age and older [45].

Advantages

The first advantage of the Janssen & Janssen vaccine is usually given as a single intramuscular dose per person[45]. The vaccine shown significant effectiveness after finishing the phase III clinical tests reached 57% in South Africa, 66% in Latin America and 72% in the USA to face the COVID-19 epidemic [46]. It is a highly effective and flexible preventive vaccine that can be stored in refrigerator temperatures at (2 to 8) °C and is suitable in environments with a high incidence of epidemic and emerging variants of COVID-19 prevention [47]. The Johnson & Johnson vaccine is authorized in the USA has been shown a significant efficiency against serious infection, deaths, delta mutated, and other variants due to infection with the emerging coronavirus according to the literature [48].

Disadvantages

Johnson & Johnson has reported six cases of blood clots with low platelet counts for more than 6.8 million doses have been given. Also, the US Food and Drug Administration and the Center Disease Control reported that being vaccinated with this vaccine had some side effects such as extreme headaches, stomach pain, leg pain, or shortness of breathing within three weeks after the vaccination. [49].

Sputnik V: The Gam-COVID-Vac vaccine (Sputnik V), has been approved in Russia as one of the viral vector-based vaccines, that is used in dual-dose relies on two types of human adenovirus [50]. Since the outbreak of the Coronavirus epidemic, the Russian Federation is considered the first country in the world to adopt the Covid-19 vaccine on August 11, 2020.[51].

Advantages

The Sputnik V vaccine is mainly based on two major immune components, namely recombinant adenovirus (rAd26, rAd5) which are among the type of viral-vector vaccine. This vaccine is used in two doses, and the interval between them is at least 21 days [50][52]. The effectiveness and safety of the Sputnik V vaccine have been verified according to the internationally reviewed data is reported as 91·6% (95% CI 85·6–95·2) according to the numbers of coronavirus cases were confirmed [53],[54],[55],[51]. The vaccine doses have been produced in the vial (0.5 /ml) that can be saved at normal degree refrigerator temperature reached at (2-8 C) [51],[29]. Some studies proved that the Russian Sputnik V vaccine was effective against the B.1.1.7 variant that was discovered in the UK, but it showed less efficacy against the B.1.351 variant, which was discovered in South Africa, especially for those vaccinated with two doses of it [56].

Disadvantages

The most prominent side effects that appeared after taking the Sputnik V vaccine, such as influenza-like disease, reactions at the injection site, headache, and weakness/lack of energy. Despite, no case of blood clump has been reported after using this vaccine so far [56] [51].

Protein-based vaccine

Protein-based or subunit-based vaccines with antigenic fragments depend on glycoprotein nanoparticles. The immune response to the protein is increased with Matrix M against COVID-19 that helps raise levels of stimulus antibodies. Basically, these vaccines use antigen or part of the antigen that plays a major role in the generation of antibodies. In this type of vaccine, different cellular protein components that are not of great importance in immunogenicity, are eliminated, which leads to a significant reduction of side effects during vaccination [57]. The advantage aspect of the vaccine, it does not contain a substance from live viruses in the composition of the antibodies to be safe during its development. Therefore, it needs at least one protein in order to stimulate the immune system to be effective. However, it needs stimuli to provide a safe and robust protective response. While, the disadvantage of the vaccine is not effective in producing adequate immunity even

if appropriate adjuvants are added [58],[59].

Novavax: The American biotechnology company Novavax announced its vaccine against the coronavirus on 28 January 2021 after completing its Phase III clinical tests in the UK. This vaccine has shown great efficacy against the mutant that appeared in the UK and South Africa. Novavax protein-based vaccine contains Spike protein that was made using nanoparticle technology recombinant with saponin-based adjuvant Matrix-M [6],[60],[61].

Advantages

Novavax vaccine given in two doses of NVX-CoV2373 (5 mcg of recombinant Spike Protein with 50 mcg of Matrix-M1) to immunize people with a 2-week interval between the two doses [62],[61],[63]. The Novavax vaccine can be saved at normal temperature (2 to 8) °C and packed into vials (5 µg of recombinant protein S with 50 µg of matrix M1) to be ready for safe use [62],[61]. This vaccine has the ability to confront the original virus SARS-CoV-2 with an efficiency of 95.6% after taking the second dose by the infectors. Also, it has been shown to be 86.6% effective against the B.1.1.7 (or alpha) variant and 60% against the B.1.351 variant [6],[61],[63]. Conversely, it has not been shown to be effective against the highly infectious delta variant [64].

Disadvantages

Some side effects of the Novavax vaccine have been reported in volunteers who received the vaccine, such as pain tenderness at the injection site, headache, muscle aches, and fatigue. [7]. However, this vaccine usually needs active adjuvants to get a stronger immune response, and sometimes these adjuvants have side effects and reactions that cause allergic reactions in this type of vaccine [65].

Nucleic acid vaccine

Any of the COVID-19 vaccines approved are called messenger RNA (mRNA), where activates the body's immune response and creates immunity against the virus. This type of vaccine depends on the mechanism used in cells to produce protein. Whereas, other vaccines depend on attenuated or inactivated elements of the disease-causing factors, thus activating the body's immune device to be able to produce antibodies to counter the virus [66]. The mechanism of action of the mRNA can be described by sending instructions to the cell and creating part of the unique 'spike protein' of SARS-CoV-2. Thus, the protein fragment that has been created does not cause any hurt to the vaccinated people but only the antigen. This information may help correct the misinformation some have about the ability of the mRNA vaccine to change or modify the genetic makeup of the vaccinated person [67],[68].

Moderna Vaccine: Moderna is an mRNA-based vaccine. This vaccine mainly depends on lipid nanoparticles to produce mRNA and it was produced after finished of phase III clinical tests on the volunteers. This vaccine targets the skeletal protein antigen in the cells of the person's body after receiving doses of the vaccine [69],[70]. The US Food and Drug Administration (FDA) provided emergency approval, to the Moderna COVID-19 vaccine at December 18, 2020. This vaccine was quickly developed to stop the widespread of the disease among the population and reduce the number of infections [71],[72].

Advantages

Moderna vaccine is taken in two doses over a period of about 28 days and is advised for people over the age of 18 years. [71],[73],[74],[75]. According to reports, an interim analysis of the clinical III tests of the vaccine was conducted, which was proven to be effective at 94.1% 14 days after taking the second dose [76],[77]. Moderna vaccine requires a relatively high temperature between (-15°C to -25°C) to be maintained and transformed [71] [77]. According to the literature, the Moderna vaccine proved to be highly effective against the epidemic variants such as alpha, beta, and gamma variants. In contrast, its efficacy against the delta variant was weaker compared to the rest of the variants [78],[79].

Disadvantages

In the USA, the Moderna vaccine has been widely used to prevent symptoms of Covid -19, with some side effects reported when teken the vaccine. According to reports, some side effects of this vaccine have been recorded after taking the vaccination such as pain at the injection place, muscle pains, sometimes slight temperature, chilliness, and malaise. [72],[74],[80].

Pfizer/BioNTech vaccine: The Pfizer-BioNTech vaccine is considered a lipid nanoparticle-formulated, or nucleoside-modified mRNA vaccine which encoded the perfusion spike glycoprotein of SARS-CoV-2 causes of the COVID-19 [81],[82]. The US Food and Drug Administration has been approved emergency use of this vaccine on December 11, 2020, to prevent the coronavirus after completing the clinical phase III trial, which distributed in the UK as a first country and also in the USA [83],[84],[85].

Advantages

The vaccine is taken in two doses of the vial (0.3 ml) to people their age over 16 years old, every 21 apart. This vaccine is expected to be given first to healthcare staff, then to residents and workers of care homes, employers, and adult students are most at risk of infection [86],[87]. The Food and Dru an Emergency Use Authorization (EUA) announced in the USA for randomized clinical trials the efficacy of the vaccine reached at (94%–95%) to prevent coronavirus-associated illness [88]. Pfizer vaccine requires a very a low temperature of -70 ° C, thus needed its storage in special refrigerated containers. Pfizer has invented temporary storage containers that keep the vaccine at low temperature for up to 30 days if frozen by

dry ice every five days [89]. According to the literature, the Pfizer vaccine has been shown highly effective against COVID-19 variants in varying proportions. It was proved significantly effective against the alpha variant after the first dose with a rate of 48.7%, and it was recorded against the delta variant at a rate of 30.7% among the participants. Whereas, this vaccine was recorded against the alpha variant after giving the two doses at a rate of 93.7% and against the delta variant at a rate of 88.0% among the subjects taking the vaccine [90].

Disadvantages

The most prominent side effects reported after taking two doses of this vaccine as pain in the area of injection, tiredness, headache, muscle hurt, joint hurt, diarrhea, high temperature, chills, sickness, and puke [85],[91].

CanSino Biological: CanSino Biologics is one of the six vaccines produced by health laboratories and companies in China. This vaccine uses a defective adenovirus platform. This vaccine modifies the adenovirus by transposing the genetic strand of SARS-CoV-2 encoded DNA (spike protein or S protein). This protein helps introduce the virus into the cell through the host body's cell membrane protein [92],[93],[94]. The National Medical Products Administration (NMPA) authorized this vaccine to use after finishing the clinical phase III trials in Wuhan on December 30, 2020 [95].

Advantages

CanSino Biologics vaccine is manufactured as a liquid formulation that fills in vials (5 x 10 viral particles of 0-5 ml) to be given as one dose per person to counter the COVID-19 epidemic [96]. This vaccine obtained final agreement for use by the National Medical Products Administration in china (NMPA) after the release of the data of the clinical phase III trials that indicated its effectiveness is at 79.34% [95]. According to the company that developed the CanSino Biologics vaccine, it can be stored at a normal temperature for a long time, ranging between (2-8 C) [97]. The CanSino vaccine showed great efficacy against the variants of Coronavirus such as alpha, beta, kappa, and gamma, except for the delta variant [31].

Disadvantages

The most prominent side effects that have been recorded about this vaccine for adults who received the vaccination are fever, tiredness, headache, muscle aches, and joint hurt [98].

In this survey, an analytical comparison was conducted for all vaccines that were approved for global use based on their parameters. Table 1 shows an analytical comparison conducted according to criteria taken into account to evaluate these vaccines.

New Research Directions

In this section, the new trend of the research topic covered based on the previous studies relevant to the survey will be described. On the other hand, the survey supporting the research topic according to the new trend is presented as follows.

In this paper, the topic of vaccines that have been approved by the World Health Organization and other healthcare-related organizations has been covered [1][2]. Several parameters have been included to describe the advantages and disadvantages in this field. Thus these parameters can represent the criteria for evaluating these vaccines alike[99][100][101][102][103]. Basically, these criteria should be taken into consideration for future studies on this topic. It is well known that all health, educational and industrial sectors rely mainly on the criteria to determine the important elements in these sectors. The multi-criteria decision-making techniques represent a promising research field to solve all the problems facing researchers, such as the health care field[104][105]. This vital field includes many important techniques in decision-making. One of these techniques is AHP to calculate the weights of the criteria for any case study, including health care sector criteria. It has been widely used recently in various scientific sectors. This technique relies on expert opinions in evaluating them according to the preferences of experts[106],[101], [99]. On the other hand, other techniques also calculate the ranking of the calculating the priority and importance of each criterion. In addition, this technique can be calculating the ranking of alternatives and alternatives based on the values of the criteria weights are taken from other methods, such as SAW, HAW, WPM, WSM, MEW, TOPSIS, VIKOR, GRA, and others[106][107][108]. On the other hand, machine learning algorithms represented the ideal direction to classify and predication for multiple vaccines that are currently produced [109]. Therefore, this trend is considered promising for many researchers to obtain reliable results based on multiple criteria for each case study.

Limitations

There are several limitations identified in this survey. The most important ones are as follows:

These vaccines were produced in a short period.

Many vaccines have not completed their clinical trials, which affects their efficacy.

Lack of information about the mechanism of manufacturing vaccines.

The side effects have been appeared after taking the vaccine.

Some vaccines have shown their inability to counter variants.

Some vaccines require special storage conditions that are not available in all countries.

Therefore, these limitations must be taken into account by researchers and developers in order to produce a more efficient vaccine against this epidemic and its variants to prevent and eliminate spread among people.

Table 1, Comparative analysis of COVID-19 vaccines

COVID-19 Vaccines	Platform of vaccine	Dose	Efficacy	Temperature of storage	Effective against delta variant	Side effects	Country of produced	Ref.
Sinopharm Vaccine	Inactivated vaccines	2 Dose	72.5% to 79.4%	2 to 8 Co	Effective against the beta bout unknown against Delta	dizziness, fatigue, headache, nausea, vomiting, fever, and atopic dermatitis	Beijing Institute, China	[19],[21],[20],[22],[23],[25]
Sinovac Institutes Vaccine		2 Dose	50.38% to 91.25%	2 to 8 Co	Effective against the gamma variant and Delta	safe and has not shown significant side effects	CoronaVac or Sinovac vaccine, Chinese company Sinovac Biotech, China	[23],[24], [28],[29], [30], [31]
Bharat Biotech Vaccine		2 Dose	81%	2 to 8 Co	efficacy against the Delta variant	injection site pain, swelling at the site, redness at the site, itching at the site, stiffness in the upper arm, weakness in the injection arm, body aches, headache, fever, malaise, weakness, rash, nausea, vomiting	Indian company Bharat Biotech, India	[32],[33],[34],[35],[5]
AstraZeneca Vaccine	Viral-vector vaccine	2 Dose	82.4%	2 to 8 Co	Effective against the delta variant	The common side effect, nausea, flu-like symptoms, and fever, as well as uncommon complications excessive sweating, swollen lymph nodes, pain, loss of appetite, and confusion	AstraZeneca and Oxford University, UK	[39], [41],[29], [42],[43], [44],[26]
Johnson & Johnson Vaccine		1Dose	57% in South Africa, 66% in Latin America, and 72% in the USA	2 to 8 Co	Effective against the delta variant, and other variants	blood clots, headaches, abdominal pain, leg pain, or shortness of breath	Johnson & Johnson company, USA	[45],[46], [47],[48], [49]
Sputnik V Vaccine		2 Dose	91.6%	2 to 8 Co	Effective against the B.1.1.7 variant and B.1.351 variant, but unknown against Delta variant	flu-like illness, injection site reactions, headache, and weakness/lack of energy	Gam-COVID-Vac, Russia	[50],[52], [53],[54],[55],[51], [29], [56]
Novavax Vaccine	Protein-based vaccine	2 Dose	95.6%	2 to 8 Co	Effective against the B.1.1.7 variant, the B.1.351 variant, and the P.1 variant. But not shown effective against delta variant	pain and tenderness at the injection site, and other side effects such as headache, muscle pain, and fatigue	American biotechnology company Novavax, USA	[62],[61],[63],[6],[64],[7], [65].
Moderna Vaccine	Nucleic acid vaccine	2 Dose	94.1%	-15°C to -25°C	Effective against the epidemic variants such as alpha, beta, gamma variants, and Delta	pain at the injection site, muscle pain, sometimes slight fever, chills, and malaise	Moderna or (Spikevax or mRNA-1273), Cambridge, US National Institutes of Health. USA	[71],[73],[74],[75], [76],[77], [72],[78], , [79], [80]
Pfizer/ BioNTech Vaccine		2 Dose	94% to 95%	-70 °C	Effective against the alpha variant and Delta variant	pain in the area of injection, fatigue, headache, muscle pain, joint pain, diarrhea, high fever and chills, nausea and vomiting	German biotechnology company BioNTech collaborated with Pfizer, an American company, Germany/ USA	[86],[87], [88],[89], [90], [85],[91]
CanSino Biological Vaccine		1 Dose	79.34%	2 to 8 Co	Effective against different variants but unknown against delta variant	fever, fatigue, headache, muscle aches, and joint pain	CanSino Biologics company, China	[96],[95], [97],[31], [98].

2. Conclusion

Since the widespread of the Coronavirus epidemic around the world, this disease has gained the attention of all health and research institutions alike. However, these vaccines still suffer have some issues that have not been addressed so far. The field of vaccine production is a major topic that requires further study and investigation. The main contribution of the study by highlighting the COVID-19 vaccines that have received final approval to be used and counter the risk of the spread coronavirus. These vaccines distributed in four main platforms have been developed in different centuries. The literature was extensively analyzed to highlight the advantages and disadvantages related to vaccines. People should be encouraged to vaccinate with these vaccines to avoid further complications of the disease and to prevent its spread between populations. This survey focused on the set of criteria related to each vaccine developed. In the future, this survey considered a cornerstone for researchers and companies that are interested in this field according to the criteria that have been referred to. These criteria can also be applied to other products.

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