FACT SHEET

How mRNA vaccines work: Safety, effectiveness and key facts

What are mRNA vaccines?

Vaccines are developed using a variety of platforms. Messenger RNA (mRNA) vaccines are an alternative to the traditional vaccine platforms that deliver antigens directly, such as live attenuated, inactivated and protein subunit vaccines. They use synthetic mRNA molecules designed to function like naturally occurring mRNA.[1] These molecules are transported into cells using various delivery vehicles—most commonly lipid nanoparticles (LNPs). LNPs protect the mRNA from rapid enzymatic degradation and promote efficient delivery into the cytoplasm, where ribosomes translate it into the specific antigen needed to induce an immune response. The mRNA does not enter the cell nucleus or integrate into DNA, and it is broken down after the antigen is produced.

Key differences in how mRNA and non-mRNA vaccines induce immunity

Vaccine type	How the vaccine works	Example(s)
Conjugate vaccine	Contains a polysaccharide antigen attached to a carrier protein	Pneumococcal conjugate and Hib vaccines
Inactivated vaccine	Delivers whole pathogen (virus or bacteria) that has been chemically or physically inactivated	Polio vaccine currently available in the United States and hepatitis A vaccine
Live attenuated vaccine	Delivers pathogen (virus or bacteria) that has been weakened	MMR, varicella and yellow fever vaccines
mRNA vaccine	Delivers transient genetic instructions for antigen production within the cytoplasm	mRNA COVID-19 and RSV vaccines
Protein subunit vaccine	Contains protein components that stimulate an immune response	Hepatitis B and HPV vaccines
Toxoid vaccine	Contains inactivated bacterial toxins	Tetanus and diphtheria vaccines
Viral vector vaccine	Uses a harmless viral carrier to deliver DNA encoding the target antigen	Ebola vaccine

Hib = *Haemophilus influenzae* type b; MMR = measles, mumps and rubella; RSV = respiratory syncytial virus.

Information from references 1-4.

Milestones in the history of mRNA vaccines

Although the mRNA COVID-19 vaccines introduced by Pfizer-BioNTech and Moderna were developed in a record 11 months during a global pandemic, the framework for these vaccines had been built several decades earlier.[5,6]

- **1961:** Work at the Pasteur Institute leads to coining the term "messenger RNA."
- **1962-63:** Animal studies conducted at Temple University and Harvard Medical School demonstrate that mRNA can function as a mobile carrier of genetic information between cells and even between different species.
- **1978:** Researchers at the University of Illinois Chicago report the use of liposomes to transfect mRNA.
- **1993:** An article published in *European Journal of Immunology* reports that injections of synthetic nonreplicating mRNA could be used as a vaccine.
- **2003:** First clinical studies investigating mRNA vaccines in humans are performed.
- **2017:** Testing leads to clinical evidence of an mRNA vaccine that, when encapsulated and delivered by an LNP, boosts immunogenicity while retaining a manageable safety profile.
- **2020:** Pfizer-BioNTech's COVID-19 vaccine is approved for emergency use on December 11, followed closely by Moderna's COVID-19 vaccine on December 18.[7] Both are mRNA vaccines that use LNP technology.
- **2021:** Pfizer-BioNTech's mRNA COVID-19 vaccine (Comirnaty) is approved by the FDA for regular use.[8]
- **2022:** Moderna's mRNA COVID-19 vaccine (Spikevax) is approved by the FDA for regular use.[9]
- **2024:** An mRNA respiratory syncytial virus (RSV) vaccine (mResvia) is approved by the FDA.[10]

Safety of mRNA vaccines for COVID-19 and RSV

Real-world surveillance reports and evidence-based studies—including large cohort studies and randomized controlled trials—show that mRNA vaccines for COVID-19 and RSV are safe.

- **Side effects of mRNA vaccines for COVID-19 and RSV are generally mild.**
  - For mRNA COVID-19 vaccines, the most frequently reported side effects after the first dose include pain at the injection site (67.8%), fatigue (30.9%), headache (25.9%) and myalgia (19.4%).[11] Higher rates of certain systemic reactions, including fatigue (53.9%), headache (46.7%) and myalgia (44.0%), have been reported after the second dose.
  - Similar side effects have been reported for the mRNA RSV vaccine.[2]
- **Serious adverse events following administration of mRNA vaccines for COVID-19 and RSV are rare.**
  - For mRNA COVID-19 vaccines, the incidence of myocarditis and/or pericarditis is approximately eight cases per million doses administered.[8,9] Risk is highest within seven days of vaccination. The highest risk group is males ages 12 to 24 years, who have an estimated incidence of 27 cases per million doses.
  - The incidence of myocarditis and/or pericarditis following mRNA COVID-19 vaccination is lower than the incidence observed following COVID-19 infection.[12]
  - To date, myocarditis and pericarditis have not been identified as safety concerns following vaccination with the mRNA RSV vaccine.[2]
- **Anaphylaxis following administration of mRNA vaccines for COVID-19 and RSV is also rare.**
  - According to Vaccine Safety Datalink (VSD) analysis, there are approximately five occurrences of anaphylaxis per million doses of mRNA COVID-19 vaccines administered.[13]
  - The rate of serious adverse events following mRNA RSV vaccination was similar to that of placebo in clinical trials.[2] There are no reports of inflammatory neurological disorders (e.g., Guillain-Barré syndrome) following administration of the mRNA RSV vaccine.

Effectiveness of mRNA vaccines for COVID-19 and RSV

Phase III clinical trials of the original mRNA COVID-19 vaccines demonstrated greater than 90% efficacy against symptomatic infection.[14,15] While currently available mRNA COVID-19 vaccines are not as effective in preventing symptomatic infection, they consistently provide meaningful protection against hospitalization, with the strongest protection against ICU admission and death.[16]

Clinical trials of the mRNA RSV vaccine demonstrated 82.4% efficacy in preventing RSV-associated lower respiratory tract disease with three or more symptoms at a median follow-up of 3.7 months after vaccination and 61.1% efficacy at a median follow-up of 8.6 months.[2,10]

> **"mRNA [vaccines are] a powerful alternative to traditional vaccines due to their high potency, safety, and efficacy, coupled with the ability for rapid clinical development, scalability and cost-effectiveness in manufacturing."[1]**

Common concerns versus key facts about mRNA vaccines

Despite strong evidence of safety and effectiveness, mRNA vaccines have faced public skepticism. When patients have concerns about mRNA vaccines, clinicians can support informed vaccination decisions by focusing on the facts.

CONCERN: "Because mRNA COVID-19 vaccines came out during a pandemic, the safety of these vaccines was not tested."

FACT: Large phase III clinical trials were still completed prior to the initial release of the mRNA COVID-19 vaccines.[14,15]

CONCERN: "An mRNA vaccine modifies human DNA."

FACT: An mRNA vaccine does not change human DNA because the mRNA never enters the cell nucleus, where DNA is stored.[1] The vaccine works by giving the body temporary instructions to make a harmless protein that induces an immune response, and then the mRNA breaks down within hours to days.

CONCERN: "COVID-19 vaccination during pregnancy will harm the unborn baby."

FACT: VSD data from 42,156 pregnancies found no increased risk of major birth defects after first-trimester mRNA COVID-19 vaccination.[17] In addition, a population-based study of 94,303 infants found no increased risk of neonatal adverse events after mRNA COVID-19 vaccination during pregnancy.[18]

What mRNA vaccines are in development?
As of July 2025, mRNA vaccine candidates against 14 viral, two bacterial and one protozoan infection were in various stages of development.[19] These include mRNA vaccines to protect against cytomegalovirus, HIV, Zika, malaria and tuberculosis. In late-stage clinical trials, some mRNA influenza vaccine candidates have shown superior efficacy in adults compared with standard-dose influenza vaccines.[20,21]

Therapeutic mRNA cancer vaccines that stimulate the immune system to destroy specific cancer cells are also being researched.[22] Targeted cancers include melanoma, prostate, pancreatic, lung and breast.

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