Evolution of the COVID-19 vaccine development landscape

In the format provided by the authors
<table>
<thead>
<tr>
<th>Candidate</th>
<th>Lead partners</th>
<th>Vaccine characteristics</th>
<th>Start of first phase I trial</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Viral vector (including replicating and non-replicating)</strong></td>
<td></td>
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<tr>
<td>Ad5-nCoV</td>
<td>CanSino Biological/Beijing Institute of Biotechnology</td>
<td>Adenovirus type 5 vector that expresses S protein</td>
<td>17 Mar 20</td>
<td>Phase II (ChiCTR2000031781) Approved for military use in China</td>
<td>CHN, CAN, UAE, PAK, MEX, BRZ, RUS</td>
</tr>
<tr>
<td>LV-SMENP-DC</td>
<td>Shenzhen GIMI</td>
<td>DCs modified with lentiviral vector expressing synthetic minigene based on domains of selected viral proteins</td>
<td>24 Mar 20</td>
<td>Phase I/II (NCT04276896)</td>
<td>CHN</td>
</tr>
<tr>
<td>AZD1222</td>
<td>AstraZeneca/Oxford University</td>
<td>ChAdOx1 vector that expresses S protein</td>
<td>23 Apr 20</td>
<td>Phase III (NCT04516746)</td>
<td>BRZ, GBR, ZAF, USA, IND, BGD</td>
</tr>
<tr>
<td>Gam-COVID-Vac</td>
<td>Gamaleya Research Institute</td>
<td>Recombinant adenovirus vector based on the human adenovirus type 5, 26, containing S protein</td>
<td>18 Jun 20</td>
<td>Phase III (NCT04530396) Conditional registration in Russia</td>
<td>RUS, KAZ, BLR, BRZ, MEX</td>
</tr>
<tr>
<td>Ad26.COV2-S</td>
<td>J&amp;J – Janssen</td>
<td>Adenovirus type 26 vector that expresses S protein</td>
<td>22 Jul 20</td>
<td>Phase I/II (NCT04436276)</td>
<td>USA, BEL, BRZ, CHL, COL, MEX, PER, PHL, ZAF, UKR, ARG</td>
</tr>
<tr>
<td>Pathogen-specific aAPC</td>
<td>Shenzhen GIMI</td>
<td>aAPCs modified with lentiviral vector expressing synthetic minigene based on domains of selected viral proteins</td>
<td>Feb 20</td>
<td>Phase I (NCT04299724)</td>
<td>CHN</td>
</tr>
<tr>
<td>GRAd-COV2</td>
<td>ReiThera Srl</td>
<td>Gorilla adenovirus vector that expresses S protein</td>
<td>24 Aug 20</td>
<td>Phase I (NCT04528641)</td>
<td>ITA</td>
</tr>
<tr>
<td>V591</td>
<td>Merck Sharp &amp; Dohme</td>
<td>Measles virus vector</td>
<td>Aug 20</td>
<td>Phase I (NCT04497298)</td>
<td>USA</td>
</tr>
<tr>
<td><strong>DNA</strong></td>
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<tr>
<td>INO-4800</td>
<td>Inovio Pharmaceuticals</td>
<td>DNA plasmid that encodes S protein delivered by electroporation</td>
<td>06 Apr 20</td>
<td>Phase I/II (NCT04336410)</td>
<td>USA, KOR, CHN</td>
</tr>
<tr>
<td>GX-19</td>
<td>Genexine Consortium</td>
<td>DNA vaccine that encodes S protein delivered by electroporation or needle free</td>
<td>19 Jun 20</td>
<td>Phase I/II (NCT04445389)</td>
<td>KOR</td>
</tr>
<tr>
<td>AG0301-COVID19</td>
<td>Osaka University/AnGes</td>
<td>DNA vaccine that encodes S protein</td>
<td>29 Jun 20</td>
<td>Phase I/II (NCT04463472)</td>
<td>JPN</td>
</tr>
<tr>
<td>ZyCoV-D</td>
<td>Zydus Cadila</td>
<td>DNA vaccine</td>
<td>15 Jul 20</td>
<td>Phase I/II (CTRI/2020/07/026352)</td>
<td>IND</td>
</tr>
<tr>
<td><strong>RNA</strong></td>
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<tr>
<td>mRNA-1273</td>
<td>Moderna Therapeutics/NIAID</td>
<td>LNP-encapsulated mRNA that encodes S protein</td>
<td>16 Mar 20</td>
<td>Phase III (NCT04470427)</td>
<td>USA</td>
</tr>
<tr>
<td>mRNA-BNT162</td>
<td>Pfizer/BioNTech</td>
<td>LNP-encapsulated mRNA that encodes stabilised S antigen</td>
<td>29 Apr 20</td>
<td>Phase II/III (NCT04368728)</td>
<td>USA, GER, ARG, BRZ, CHN and others</td>
</tr>
<tr>
<td>CVnCoV</td>
<td>CureVac</td>
<td>LNP-encapsulated mRNA that encodes the S protein</td>
<td>19 Jun 20</td>
<td>Phase I (NCT04449278)</td>
<td>GER, BEL</td>
</tr>
<tr>
<td>LNP-nCoVsaRNA</td>
<td>Imperial College London</td>
<td>LNP-encapsulated self-amplifying RNA that encodes the S protein</td>
<td>19 Jun 20</td>
<td>Phase I/II (ISRCTN17072692)</td>
<td>GBR</td>
</tr>
<tr>
<td>mRNA</td>
<td>Walvax Biotechnology</td>
<td>mRNA encoding the RBD</td>
<td>25 Jun 20</td>
<td>Phase I (ChiCTR2000034112)</td>
<td>CHN</td>
</tr>
<tr>
<td>ARCT-021</td>
<td>Arcturus Therapeutics</td>
<td>LNP-encapsulated self-replicating mRNA that encodes the prefusion S protein</td>
<td>12 Aug 20</td>
<td>Phase I/II (NCT04480957)</td>
<td>SGN</td>
</tr>
</tbody>
</table>
### Table 1 cont. | COVID-19 vaccines in clinical development

<table>
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<tr>
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<tr>
<td><strong>Inactivated virus</strong></td>
<td></td>
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<tr>
<td>Inactivated SARS-CoV-2 vaccine</td>
<td>Wuhan Institute of Biological Products/ Sinopharm</td>
<td>Inactivated novel coronavirus Pneumonia vaccine (Vero cells)</td>
<td>11 Apr 20</td>
<td>Phase III (ChiCTR2000034780)</td>
<td>CHN, UAE, MAR</td>
</tr>
<tr>
<td>Adsorbed COVID-19 (inactivated) vaccine</td>
<td>Sinovac Biotech</td>
<td>SARS-CoV-2 inactivated vaccine</td>
<td>16 Apr 20</td>
<td>Phase III (NCT04456595)</td>
<td>CHN, BRZ, BGD, CHL, IND, TUR</td>
</tr>
<tr>
<td>Inactivated SARS-CoV-2 vaccine</td>
<td>Beijing Institute of Biotechnology/ Sinopharm</td>
<td>Inactivated novel coronavirus (2019-CoV) vaccine (Vero cells)</td>
<td>28 Apr 20</td>
<td>Phase II/II (ChiCTR2000032459)</td>
<td>CHN</td>
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<tr>
<td>Inactivated SARS-CoV-2 vaccine</td>
<td>Institute of Medical Biology, Chinese Academy of Medical Sciences</td>
<td>SARS-CoV-2 inactivated vaccine</td>
<td>15 May 20</td>
<td>Phase II/II (NCT04470609)</td>
<td>CHN</td>
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<tr>
<td>BBV 152</td>
<td>Bharat Biotech</td>
<td>Whole-virion inactivated</td>
<td>14 July 20</td>
<td>Phase II/II (CTRI/2020/07/026300)</td>
<td>IND</td>
</tr>
<tr>
<td><strong>Protein-based (including recombinant protein, virus-like particle, peptide-based)</strong></td>
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<tr>
<td>NVX-CoV2373</td>
<td>Novavax</td>
<td>Stable, prefusion protein, includes MatrixM™ adjuvant</td>
<td>25 May 20</td>
<td>Phase II (NCT04368988)</td>
<td>AUS, USA, ZAF</td>
</tr>
<tr>
<td>SCB-2019</td>
<td>Clover Biopharmaceuticals</td>
<td>Recombinant SARS-CoV-2 trimeric S protein subunit vaccine</td>
<td>19 Jun 20</td>
<td>Phase I (NCT04405908)</td>
<td>AUS</td>
</tr>
<tr>
<td>Recombinant new coronavirus vaccine (CHO cell)</td>
<td>Anhui Zhifei Longcom Biopharmaceutical/ IMCAS</td>
<td>Recombinant SARS-CoV-2 RBD protein subunit vaccine</td>
<td>22 Jun 20</td>
<td>Phase II (NCT04466085)</td>
<td>CHN</td>
</tr>
<tr>
<td>Covax-19</td>
<td>Vaxine Pty/Medicago</td>
<td>Recombinant SARS-CoV-2 spike protein with Advax-SM adjuvant</td>
<td>01 July 20</td>
<td>Phase I (NCT04453852)</td>
<td>AUS</td>
</tr>
<tr>
<td>UQ-1-SARS-CoV-2-Sclamp</td>
<td>University of Queensland/CSL</td>
<td>Recombinant SARS-CoV-2 spike protein 'molecular clamp' plus MF59 adjuvant</td>
<td>13 July 20</td>
<td>Phase I (ACTRN12620000674932p)</td>
<td>AUS</td>
</tr>
<tr>
<td>Coronavirus-like particle COVID-19 vaccine</td>
<td>Medicago</td>
<td>Plant-derived virus-like particle with/without ASO3 or CPG1018 adjuvant</td>
<td>13 Jul 20</td>
<td>Phase I (NCT04450004)</td>
<td>CAN</td>
</tr>
<tr>
<td>EpiVacCorona</td>
<td>FBR5SRC VB VECTOR</td>
<td>Synthesized peptide antigens of SARS-CoV-2 proteins</td>
<td>27 Jul 20</td>
<td>Phase I/II (NCT04527575)</td>
<td>RUS</td>
</tr>
<tr>
<td>Soberana 01</td>
<td>Instituto Finlay de Vacunas</td>
<td>RBD with adjuvant</td>
<td>24 Aug 20</td>
<td>Phase I/II (IFV/COR/04)</td>
<td>CUB</td>
</tr>
<tr>
<td>Recombinant SARS-CoV-2 vaccine</td>
<td>Sichuan University</td>
<td>Recombinant SARS-CoV-2 vaccine (Sf9 cell)</td>
<td>28 Aug 20</td>
<td>Phase I (ChiCTR2000037518)</td>
<td>CHN</td>
</tr>
<tr>
<td>Adjuvanted recombinant protein-based vaccine</td>
<td>Sanofi / GSK</td>
<td>Recombinant protein-based S protein vaccine together with ASO3</td>
<td>Sep 20</td>
<td>Phase I (NCT04537208)</td>
<td>USA</td>
</tr>
</tbody>
</table>

*The table includes candidates that have started dosing the first patient. The candidates are ordered by platform and the start date of the first phase I trial. The data is from 3 September 2020; see Supplementary Box 1 for details. aAPC, artificial antigen-presenting cell; DC, dendritic cell; LNP, lipid nanoparticle; RBD, receptor-binding domain.