SARS-CoV-2 and COVID-19

EPIDEMIOLOGY

Transmission Dynamics. Person-to-person transmission documented with mean incubation period 5.2 d, serial interval 7.5 d, reproductive number approximately 2.2 (Li, NEJM); Inter-individual contact data can be used to estimate R0 (reproduction number) in health care facilities to inform infection control measures (Temime, MedRxiv)

Families. Family clusters observed (Chan, Lancet); estimated transmission risk ranges from 1-16% among household contacts (Wu CROI presentation, https://special.croi.capitalreach.com/; Li, Clin Infect Dis); family gatherings may facilitate community spread (Ghinai, MMWR); cats may be infected and exhibit asymptomatic transmission to other cats, but it is unknown if they can transmit SARS-CoV-2 to humans (Halfmann, NEJM)

Children. Infection is common in children but most are asymptomatic or mild, including early neonatal infections (Cai, Clin Infect Dis; Lu, NEJM; Dong, Pediatrics; Qiu, Lancet Infect Dis; Zeng, JAMA Pediatr; Wei, JAMA; Castagnoli, JAMA Pediatr; Parri, NEJM); most children requiring hospitalization for COVID-19 have comorbidities (Shekerdemian, JAMA Pediatr); children may still contribute to transmission and have viral loads comparable to adults (Jones, Charite preprint); association with Kawasaki Disease-like syndrome (Jones, Hosp Pediatr; Riphagen, Lancet), that tends to occur in older children than classical Kawasaki disease and has a higher rate of cardiac involvement and macrophage-activation syndrome that may require steroid therapy (Verdoni, Lancet)

Asymptomatic Transmission. Asymptomatic or pre-symptomatic transmission makes an important contribution to spread (Rothe, NEJM; Yu, J Infect Dis; Bai, JAMA; Tong, Emerg Infect Dis; Li, Science; Xia, MedRxiv; Tao, MedRxiv; Qian, Clin Infect Dis; Wei, MMWR; Cheng, JAMA Intern Med; Furukawa, Emerg Infect Dis); this is further supported by comparison of the transmission interval and incubation period in China, Japan and Singapore (Nishiura, Int J Infect Dis; Tindale, MedRxiv); over half of PCR-positive residents of Life Care Center of Kirkland were asymptomatic on initial testing, and viral load did not correlate with the presence of symptoms (Kimball, MMWR; Arons, NEJM), which has also been noted in Italy (Cereda, ArXiv); SARS-CoV-2 spread prior to symptom onset or by patients with mild atypical symptoms has been documented (Bohmer, Lancet Infect Dis), and possible transmission by hand shaking and face-to-face contact by a presymptomatic individual reported (Hijnen, Emerg Infect Dis); contact tracing and testing revealed 20% of secondary cases to be asymptomatic at the time of first clinical assessment (Bi, Lancet Infect Dis); 43% of SARS-CoV-2-positive persons detected in population-based screening in Iceland denied symptoms (Gudbjartsson, NEJM); containment measures, movement restrictions and increased awareness may shorten the window of transmission (Zhang, Lancet Infect Dis)

Superspreaders. Superspreader events appear to be associated with explosive growth and sustained transmission of COVID-19 (https://wwwnc.cdc.gov/eid/article/26/6/20-0495_article);
Viral Shedding. High pharyngeal viral shedding on day zero is seen with a subsequent decline, more like influenza than SARS (He, MedRxiv; Zou, NEJM; To, Lancet Infect Dis), but some patients may continue to be PCR-positive (Lan, JAMA). PCR-positivity persists for 7-12 days in mild-moderate cases but longer in severe cases (Wu CROI presentation https://special.croi.capitalreach.com/arc/audD3b/o1

Washington State. First US cases in Washington State described (Holshue, NEJM; Arentz, JAMA); COVID-19 detected in all 50 states by early March, and genomic epidemiology suggests the importance of cryptic domestic spread (Fauver, MedRxiv; Bedford, MedRxiv); surveillance by the Seattle Flu Study detected early SARS-CoV-2 circulation (Chu, NEJM); Life Care Center of Kirkland outbreak ended up involving 101 residents, 50 HCWs and 16 visitors (McMichael NEJM); links with other LTCFs involving shared staff or patients were identified

Community Prevalence. High prevalence found when screening homeless shelter residents and staff in Boston, Seattle and San Francisco (Baggett, JAMA; Mosites, MWR); a mobile community, crowding, asymptomatic transmission and lack of face coverings are thought to contribute to the high rates of COVID-19 in homeless shelters (Tobolowsky, MMWR); meat and poultry facilities appear to be high-risk settings: 4,913 cases of COVID-19 with 20 deaths reported in 115 U.S. facilities (Dyal, MMWR); a survey estimated SARS-CoV-2 seroprevalence to be 2.8% in Santa Clara County (Bendavid, MedRxiv), which is unexpectedly high (but concerns have been raised regarding sampling bias, inconsistency with rates of SARS-CoV-2 spread and mortality in other communities, and the likelihood of false-positive results); may already have been spreading in France in late December (Deslandes, Int J Antimicrob Agents)

Cruise Ships. Recent outbreaks on cruise ships resulted in more than 800 infections and 10 deaths (Moriarty, MMWR)

Seasonal Factors. Inverse relationship observed between temperature/humidity and transmission (Wang, MedRxiv; Ma, MedRxiv; Oliveira, MedRxiv; Araujo, MedRxiv; Neher, MedRxiv; Sajadi, SSRN; Bukhari, SSRN); vitamin D deficiency correlates with severity in men (De Smet, MedRxiv)

Environmental Stability. SARS-CoV-2 may remain detectable in aerosols for at least 3 h and is more stable on plastic/steel than on copper/cardboard; inactivated by 70% ethanol, 0.5% hydrogen peroxide or 0.1% bleach but less reliably by benzalkonium chloride or chlorhexidine (Kampf, J Hosp Infect; van Doremalen, NEJM)
**Possible Effects of BCG.** Attributable mortality is lower in BCG vaccine-using countries (Miller, MedRxiv; Shet, MedRxiv); however, the purported relationship between BCG and COVID-19 susceptibility is being heavily criticized because of testing, time and selection bias (Szigeti, MedRxiv) and failure to control for confounding by population age (Kirov, MedRxiv); BCG-vaccinated or unvaccinated adults in Israel had similar rates of COVID-19 infection (Hamiel, JAMA)

**VIROLOGY**

**SARS-CoV-2 Virus.** Description of SARS-CoV-2 (Zhu, NEJM; Lu, Lancet; Wu, Nature)

**Relation to Other Coronaviruses.** 88-96% similarity to bat coronaviruses (Zhou, Nature); pangolin suggested as reservoir host (Zhang, Curr Biol; Lam, Nature; Xiao, Nature), used for food and traditional Chinese medicine, but pangolin coronaviruses lack a furin cleavage site found in SARS-CoV-2 and pangolin coronaviruses are genetically related but distinct from SARS-CoV-2 (Liu, PLoS Pathog)

**Binding.** Structure of spike protein and binding to ACE2 (Wrapp, Science; Yan, Science; Hoffmann, Cell; Walls, Cell); the distribution of tissue ACE2 expression may explain higher viral loads in the lower respiratory tract; ACE2 expressed in airways, cornea, GI tract, liver, heart, kidney, testis (Sungnak, Nat Med); productive infection of human gut epithelial cells has been demonstrated (Lamers, Science)

**Furin Cleavage.** Furin-like cleavage site in the spike glycoprotein may broaden cell tropism (Coutard, Antiviral Res)

**Subtypes.** Possible subtypes with differences in virulence (Tang, Nat Sci Rev; Xi, MedRxiv; Su, BioRxiv; Korber, BioRxiv)

**Immune Response.** The distinctive immune responses to SARS-CoV-2 play a major role in disease severity and mortality (Vabret, Immunity); increased antibody-secreting cells (ASCs), follicular helper T cells (Tfh cells), activated CD4+/CD8+ T cells and IgM/IgG SARS-CoV-2-binding antibodies were observed in a patient with non-severe COVID-19 prior to recovery, suggesting that they might provide a correlate of favorable outcomes and protective immunity (Thevarajan, Nat Med); virus-specific T cells detected in recovered patients, which correlated with neutralizing Ab titers (Ni, Immunity); reappearance of effector and memory T cells correlates with recovery (Odak, MedRxiv); SARS-CoV-2-specific CD4+ and CD8+ T cell responses are detected in convalescing COVID-19 patients, but also to a lesser extent in in unexposed individuals, which may represent cross-reactivity with seasonal respiratory coronaviruses (Grifoni, Cell; Braun, MedRxiv); possible immunopathological mechanisms include antibody-dependent enhancement and promotion of Th2 responses (Peeples, PNAS)
**Immune Evasion.** Transcriptomic response suggests a muted antiviral response compared to other respiratory viruses (Blanco-Melo, BioRxiv); weak induction of interferon responses is observed (Chu, Clin Infect Dis; O’Brien, Clin Infect Dis); STAT2 signaling appears to play a role in both antiviral defense and immunopathology in a hamster model, suggesting that immunomodulators may potentially have mixed effects (Boudewijns, BioRxiv); like other subacute viral infections, may cause T-cell exhaustion as well as depletion (Vardhana, J Exp Med)

**Complement Activation.** Viral N protein induces complement activation, which may contribute to acute lung injury (Gao, MedRxiv)

**Interaction with Olfactory Epithelium.** Sustentacular cells in the olfactory neuroepithelium express the ACE2 receptor and TMPRSS2 protease required for viral attachment and entry (Bilinska, ACS Chem Neuro; Fodoulian, BioRxiv); this may help to explain COVID-19-associated anosmia

**Animal Models.** Syrian hamsters can be used to study transmission, pathogenesis, treatment and immunization (Chan, Clin Infect Dis); SARS-CoV-2 replicates throughout the respiratory tract in a macaque model and recapitulates features of moderate human COVID-19 (Rockx, Science; Munster, Nature); causes interstitial pneumonia in transgenic mice expressing human ACE2 (Bao, Nature); a mouse-adapted model in which the spike protein and ACE2 protein have been modified to allow efficient interaction recapitulates SARS-CoV-2 replication in the respiratory tract, more severe illness in aged mice and protection by IFNλ (Dinnon, BioRxiv)

**Autopsy Pathology.** Autopsy findings in patients with COVID-19-associated ARDS shows edema, proteinaceous exudate, focal reactive pneumocyte hyperplasia, patchy inflammatory cellular infiltration, and multinucleate giant cells consistent with diffuse alveolar damage similar to SARS/MERS (Xu, Lancet Respir Med; Liu, J Med Virol); spleens and lymph nodes show lymphocyte depletion and virus-infected macrophages producing IL-6 (Feng, MedRxiv), which are implicated in the pathogenesis of a “cytokine storm” (Merad, Nat Rev Immunol); a striking finding is capillary congestion and microthrombi, generally but not always restricted to the lungs (Fox, MedRxiv; Dolhnikoff, J Thromb Haemost; Carsana, MedRxiv; Marini, JAMA suppl; Menter, Histopathology), although autopsies of Washington State patients, many of whom were from a long-term care facility, found diffuse alveolar damage and virus in type I and II pneumocytes but no microthrombi (Bradley, MedRxiv); some patients show pulmonary septal capillary injury with complement/fibrin deposition in the microvasculature rather than classic ARDS (Magro, Transl Res); endothelial infection by SARS-CoV-2 may promote microvascular dysfunction and thrombosis (Varga, Lancet); clinically unsuspected deep venous thrombosis and pulmonary embolism have also been noted (Wichmann, Ann Intern Med); SARS-CoV-2 found in kidneys, liver, heart and brain (Puelles, NEJM)
Incubation Period. Incubation period usually 4-5 d, most within 14 d (Chan, Lancet; Lauer, Ann Intern Med); incubation period may range up to 24 d in exceptional cases (Nie, J Infect Dis)

Usual Clinical Presentation. Male > female, median age 49 y, fever, cough, myalgia, fatigue, dyspnea, lymphopenia, ARDS, cardiac injury; myalgias, confusion, headache, sore throat, coryza, chest pain, secondary infection infrequent (Huang, Lancet; Chen, Lancet; Wang, JAMA; Xu, BMJ; Guan, NEJM); rates of hospitalization and mortality higher in men (Garg, MMWR; Lewnard, MedRxiv; Prieto-Alhambra, MedRxiv); SARS-CoV-2-positive patients in the ED are more likely to report fever, fatigue or myalgias, and to have lymphopenia/CXR infiltrates (Shah, MedRxiv); another series found predictors of COVID-19 to include exposure history, fatigue, leukopenia or lymphopenia and ground glass opacities on imaging (Mao, Lancet Digital Health)

Other Signs and Symptoms. A prospective study of 16,749 people with COVID-19 in the UK found distinct respiratory, systemic and enteric presentations (Docherty, MedRxiv); may present with mild URI symptoms, particularly in young healthy persons (Arashiro, Emerg Infect Dis; Woelfel, Nature); GI symptoms infrequent in some series but may be the primary presenting symptoms in a subset of patients (Pan, Am J Gastroenterol; D’Amico, Clin Gastroenterol Hepatol) and can include abdominal pain in absence of fever (Gahide, Clin Med); GI symptoms may be associated with milder illness (Nobel, Gastroenterology; Han, Am J Gastroenterol; Buscarini, MedRxiv) but have also been reported to be a risk factor for hospitalization and complications (Cholankeril, Gastroenterology; Mao, Lancet Gastroenterol Hepatol); >85% of patients with mild-moderate COVID-19 may report alteration or loss of taste/smell (Iacobucci, BMJ; Lechien, Eur Arch Oto-Rhinol Laryngol; Spinato, JAMA; Luers, Clin Infect Dis); most patients with anosmia/dysgeusia recover quickly (Levinson, MedRiv); ocular signs may include conjunctival hyperemia, chemosis, epiphora or ocular secretions (Wu, JAMA Ophthalmol); cutaneous findings include acral erythema/chilblains, vesicular eruptions, urticaria, maculopapular rash and livedo or necrosis (Casas, Br J Dermatol; de Masson, JAAD)

Course of Pre-symptomatic Infections. Pre-symptomatic cases detected on screening usually result in mild disease (Wang, J Infect Dis)

Fever. Although fever is a common feature of COVID-19, only half of Seattle patients requiring ICU admission for severe COVID-19 were febrile on admission (Bhatraju, NEJM); a biphasic illness is seen in severe cases, with fever at the onset of illness and again in the second week of illness at the time of acute deterioration and ARDS (https://youtu.be/Om9VTacb6VM; Kujawski, Nat Med); in patients with acute deterioration, viral load may indicate whether antiviral or immunomodulatory therapy is more likely to be beneficial (Lescure, Lancet Infect Dis; Joynt, Lancet Infect Dis)

Laboratory Findings. Lymphopenia (Tan, MedRxiv), eosinopenia (Li, MedRxiv) and elevated NLR (neutrophil-to-lymphocyte ratio, Qin, Clin Infect Dis; Liu, J Infect) are predictive of more severe illness; elevated LDH, ferritin, LFTs, IL-2R/IL-6/IL-10/TNFα and reduced CD4+/CD8+ T cells common (Chen, J Clin Invest; Pedersen, J Clin Invest; Wang, JCI Insight), procalcitonin may
be elevated; Lymphopenia, elevated D-dimer ≥2.0 mcg/ml, CRP, procalcitonin predictive of mortality (Paranjpe, MedRxiv; Zhang, J Thromb Haemost)

Hypercoagulable State. Abnormal coagulation parameters are common and associated with increased mortality risk (Tang, J Thromb Haemost; Lillicrap, J Thromb Haemost; Violi, Throm Haemost); coagulopathy, endothelial damage and inflammation can promote thrombosis (Connors, Blood); inflammatory thrombotic process primarily in the lungs is common to SARS and COVID-19 (McGonagle, Lancet Rheumatol); anti-phospholipid antibodies or lupus anticoagulant may be detected in the setting of coagulopathy and multifocal thrombosis (Zhang, NEJM; Harzallah, J Thromb Haemost; Bowles, NEJM); thromboelastography more consistent with an inflammatory hypercoagulable state than with DIC (Panigada, J Thromb Haemost; Spiezia, Thromb Haemost; Lawicki, MedRxiv); ~30% incidence of thrombotic complications in ICU patients with COVID-19 (Klok, Thromb Res); high risk of venous thromboembolism and pulmonary embolism in patients with severe COVID-19 (Lodigiani, Thromb Res), even on therapeutic anticoagulation (Llitjos, J Thromb Haemost)

Radiographic Findings. Chest CT shows multifocal ground-glass opacities, but findings overlap with other causes of viral pneumonitis (Chung, Radiology; Zhou, AJR; Shi, Lancet Infect Dis; Li, AJR); most discriminating chest CT features of COVID-19 pneumonia are peripheral distribution, ground glass opacities and vascular thickening (Bai, Radiology); other chest CT findings include air-bronchograms, crazy paving pattern, consolidation, patchy infiltrates, spider-web sign, or cord-like and nodular lesions; pleural thickening sometimes seen but lymphadenopathy and pleural effusions are rare (Zhu, J Med Virol); may be abnormal in asymptomatic individuals (Hu, Sci China Life Sci); consensus guidelines for the use of chest imaging are available (Rubin, Radiology); electrical impedance tomography suggests distinctive pulmonary physiology in some patients with severe COVID-19 with more ventilated/nonperfused units, consistent with vasculopathy (Mauri, Crit Care Med)

Ultrasound. Lung ultrasound may show pleural thickening, B lines and consolidation (Peng, Intensive Care Med)

Risk Factors and Outcomes. Case-Fatality Rate 1.38% with a strong age-gradient (Verity, MedRxiv; Wu, Nature Med); most deaths occur in patients with co-morbidities including cardiovascular/pulmonary disease and diabetes (Wu, JAMA; Zhou, Lancet; Guan, MedRxiv; COVID-19 Response Team, MMWR); a large UK study analyzing health records of >17 million adults found a strong correlation between mortality and age, sex, obesity, diabetes, recent diagnosis of malignancy and organ transplant (Williamson, MedRxiv); illness may be more severe in Blacks (Gold, MMWR); higher CFR reported in Italy, attributable to more patients ≥70 years of age (Onder, JAMA); although CFR is highest in older patients, a substantial number of patients aged 20-64 are requiring hospitalization and ICU admission (COVID-19 Response Team, MMWR; Myers, JAMA); hypoxemia is independently associated with mortality (Xie, Mayo Clin Proc); dyspnea, ARDS and cardiac injury (elevated troponin T) are associated with fatal outcomes (Chen, BMJ; Guo, JAMA Cardiol; Gupta, JAHA); hyperkalemia, acute kidney injury and hypoxic encephalopathy may also be seen; mortality in patients requiring ICU admission may be
~25% (Grasselli, JAMA); high SOFA score is predictive of mortality (OR 5.65; Zhou, Lancet); 28d survival 61% in patients requiring ICU admission (Wang, AJRCCM); reported mortality in patients requiring mechanical ventilation has varied widely from 17-88%, but unclear if patient populations are comparable and some estimates inflated due to incomplete follow-up (Richardson, JAMA; Auld, MedRxiv; Petrilli, MedRxiv; Docherty, MedRxiv; Ziehr, NEJM); patients requiring mechanical ventilation nearly always require vasopressor support (Goyal, NEJM); risk factors for severe illness are age, obesity, comorbidities, dyspnea, hemoptyis, loss of consciousness, O2 sat <88% and elevated D-dimer/ferritin/CRP/NLR, azotemia/elevated LFTs (Petrilli, MedRxiv; Lighter, Clin Infect Dis; Wang, MedRxiv; Liang, JAMA Intern Med); from Feb-Apr 2020, COVID-19 was calculated to have caused 21 times more deaths than seasonal influenza in NYC (Faust, MedRxiv)

**Cardiac and Neurologic Complications.** Pre-existing cardiovascular disease is a risk factor for more severe disease, and COVID-19 can have a variety of cardiovascular complications (Driggin, JACC; Guzik, Cardiovasc Res); cardiac injury more common in severe illness (Hui, MedRxiv), which can be accompanied by arrhythmias and may be due to the presence of ACE2 on cardiac myocytes (Zheng, Nat Rev Cardiol; Wang, JAMA clinical); cardiac injury is an independent risk factor for in-hospital mortality (Shi, JAMA Cardiology); 58% increase in out-of-hospital cardiac arrest observed during the COVID-19 outbreak in Italy (Baldi, NEJM); cor pulmonale may occur, most likely due to thromboembolic disease (Creel-Bulos, NEJM); neurologic abnormalities are not uncommon but may result from indirect mechanisms (Mao, JAMA Neurol); acute CVA may be a presentation of COVID-19, including patients <50 yrs of age (Oxley, NEJM); Guillain-Barré Syndrome has been reported (Toscano, NEJM)

**Cytokine Storm.** Cytokine storm and elevated IL-6 levels produced by macrophages seen in severe illness (Wang, Clin Infect Dis; Chen, MedRxiv; Wang (2), MedRxiv; Yang, MedRxiv; Moore, Science; Tay, Nat Rev Immunol; Merad, Nat Rev Immunol); IL-6 levels ≥80 pg/ml associated with 22-fold increased risk of respiratory failure (Herold, MedRxiv)

**Immunocompromised Hosts.** Rates of hospitalization in patients on immunosuppressive therapy in NYC were comparable to the general population (Haberman, NEJM); some immunocompromised populations have been reported to have a generally favorable prognosis (Minotti, J Infect), but a higher case-fatality rate has been observed for patients with cancer in NYC (Mehta, Cancer Discov), and kidney transplant recipients in NYC had a high early mortality (28% at 3 wks) (Akalin, NEJM); among cancer patients with COVID-19, age ≥65 and treatment with immune checkpoint inhibitors are risk factors for hospitalization and severe outcomes (Robilotti, MedRxiv); clinical presentation in patients with HIV is variable (Blanco, Lancet HIV); others have reported that immunocompromised patients (autoimmune disease, cancer, organ transplant) are less likely to develop moderate-severe ARDS (Monreal, Res Sq preprint)

**Pregnancy.** Clinical course similar in pregnant women without definitive evidence of intrauterine or transplacental transmission (Chen, Lancet; Schwartz, Arch Pathol Lab Med; Chen, NEJM); detection of antibodies including IgM in newborns of SARS-CoV-2-infected mothers suggests possible in utero infection, but virus not detected (Dong, JAMA; Zeng, JAMA;
Kimberlin, JAMA); may be an increased risk of preterm delivery (Mullins, Ultrasound Obstet Gynecol; Wang, Clin Infect Dis); a case of preeclampsia in the 2nd trimester associated with placental infection reported (Hosier, MedRxiv); 88% of COVID-positive pregnant women admitted for delivery during the NYC epidemic were asymptomatic (Sutton, NEJM)

**Impact on Surgical Outcomes.** Asymptomatic patients with COVID-19 who undergo elective surgery may have unexpectedly poor outcomes, with 44% requiring ICU care and 21% mortality (Lei, EClinicalMedicine)

**LABORATORY DIAGNOSIS**

**Diagnostic Tests.** Diagnostic testing plays an extremely important role in COVID-19 control, but there are still major unmet needs in the diagnostic pipeline (Cheng, Ann Intern Med); testing availability in the U.S. has been uneven and inadequate (Schneider, NEJM); demographic data, labs (CRP, LDH, ferritin, neutrophil/lymphocyte counts) and x-ray/CT can be used for a presumptive diagnosis of COVID-19 with 96% sensitivity and 95% specificity (Kurstjens, MedRxiv); RT-PCR is the standard method for SARS-CoV-2 detection, and sensitive commercial assays are available (Zhen, J Clin Microbiol); IDSA diagnostic guidelines published (Hanson, IDSA guidelines); point-of-care (POC) tests under development or in process of assessment (Loeffelholz, Emerg Microbes Infect; Joung, MedRxiv)

**Clinical Specimens for Viral Detection by Nucleic Acid Amplification Tests (NAAT).** Sequential utility of specimen types: upper respiratory specimens more sensitive early in illness, lower respiratory tract specimens more sensitive later, fecal specimens remain positive the longest (Song, J Med Virol); PCR of Sputum or BALF is more sensitive than upper respiratory specimens (Wang, JAMA: Han, Lancet Infect Dis; Lin, MedRxiv; Loeffelholz, Emerg Microbes Infect; Cheng, Ann Intern Med; Wu, Travel Med Infect Dis); PCR sensitivity parallels higher viral load in sputum compared to nasopharyngeal or throat swabs (Zou, NEJM; Yu, Clin Infect Dis); viral load at the time of admission may be predictive of disease severity and prognosis (Liu, Lancet Infect Dis); differences observed in the sensitivity of primer-probe sets used to detect SARS-CoV-2, with E gene (Charité), ORF1 (HKU) and N1 (US CDC) more sensitive than RdRp-SARSr (Charité) (Vogels, MedRxiv); most commercial assays are comparably sensitive and specific (Lieberman, J Clin Microbiol), but the Abbott ID NOW rapid NAAT assay is reported to have lower specificity than conventional PCR assays (Basu, BioRxiv)

**Limitations of PCR.** Sensitivity of RT-PCR is highest during first few days of symptoms (Kucirka, Ann Intern Med); a negative NP/OP swab does not rule-out COVID-19 (Winichakoon, J Clin Microbiol; Long, Eur J Radiol); yield of re-testing depends on local prevalence (Green, MedRxiv; Long, MedRxiv); PCR assays may revert to positive in a minority of patients, clinical significance of this is unknown (Yuan, Clin Infect Dis)

**Other Specimens.** Virus detected in urine, blood, anal swabs, saliva (To, Clin Infect Dis; Peng, MedRxiv; Tang, J Clin Microbiol); self-collected tongue, nasal, saliva or mid-turbinate swabs
appear comparable to health care worker-collected nasopharyngeal swabs (Tu, MedRxiv; Wehrhahn, MedRxiv; Kojima, MedRxiv; Wyllie, MedRxiv; Williams, J Clin Microbiol; Jamal, MedRxiv; Berenger, MedRxiv); viral loads in saliva reportedly comparable to those in nasopharyngeal swabs and may be detected up to 20 days post-symptom onset, correlating with illness severity (Khurshid, MedRxiv), but others have found lower sensitivity of saliva (Becker, MedRxiv)

**Viral Shedding.** PCR may continue to detect viral RNA for weeks, but cultures of respiratory secretions in patients with mild illness become negative after 8 days (Woelfel, MedRxiv); more severely ill patients may continue to exhibit detectable viral RNA in lower respiratory tract specimens for weeks to months (Huang, AJRCCM; Zheng, BMJ; Xiao, Clin Infect Dis; Wajnberg, MedRxiv; Xiao, J Clin Virol); viral RNA can also be found in stool for weeks, but there is currently little evidence of fecal-oral transmission (Pan, Lancet Infect Dis; Gu, Gastroenterology; Wu, Lancet Gastroenterol Hepatol; Chan, Ann Intern Med; Cheung, Gastroenterology; Xu, Nat Med)

**Co-Infections.** Co-infections may be present (Lin, Sci China Life Sci; Kim, JAMA)

**Adjunctive Role of CT Scanning.** Chest CT may show abnormalities even when PCR is negative (Fang, Radiology; Ai, Radiology); however, in low prevalence regions, positive predictive value of RT-PCR far greater than that of chest CT (Kim, Radiology); chest findings consistent with COVID-19 may be detected as an incidental finding when patients with atypical presentations undergo spine/neck or abdomen/pelvis CT scanning (Hossain, Radiology); dual-energy CT may detect regions of decreased perfusion surrounded by a halo of higher perfusion indicative of disrupted pulmonary vasoregulation (Lang, Lancet Infect Dis)

**Serology.** Many issues relating to serologic testing remain to be defined (Theel, J Clin Microbiol); limited clinical and experimental data suggest that recovery from COVID-19 may confer immunity to reinfection (Kircaldy, JAMA); Ab begins to be detected as viral load declines (Sethuraman, JAMA); serologic tests vary in sensitivity and specificity, ranging from 68-93% sensitivity for IgM and 65-100% for IgG, with high specificity for most assays (98%) (Okba, MedRxiv; Whitman, MedRxiv; Caini, MedRxiv); IgG more sensitive than IgM, but IgM and IgG exhibit similar kinetics (Jin, Int J Infect Dis; Xiang, Clin Infect Dis); combination of RT-PCR and serology may enhance case detection (Guo, Clin Infect Dis; Zhao, Clin Infect Dis 2; Zhang, J Infect Dis); many patients seroconvert within 14 d of symptom onset, and most seroconvert by 20d (Long, Nat Med; To, Lancet Infect Dis; Lou, MedRxiv); Ab titers correlate with disease severity (Zhao, Clin Infect Dis); community seroprevalence comparable in children/middle-aged adults and lower in older adults (Stringhini, MedRxiv); commercial assays exhibit considerable variation in sensitivity and specificity (Lassauniere, MedRxiv); neutralizing Ab may be detected within 6 days of diagnosis (Suthar, MedRxiv), but titers are variable in recovered patients and correlate with CRP and lymphopenia (Wu, MedRxiv); false negative serologies may result from waning antibody levels, and sensitivity of serology in subclinical infection is presently unknown, but seroconversion may not occur in some asymptomatic infections (Zhang, Emerg Microbes Infect); subclinical seroconversion was observed among HCWs and patients in a pediatric
dialysis unit (Hains, JAMA); antibody titers do not necessarily mean immunity, and protection may be transient (Huang, MedRxiv)

**Biosafety.** Clinical lab safety recommendations have been published (Iwen, Am J Clin Pathol)

**TREATMENT**

**Investigational Agents.** A large number of potential therapeutic agents is under investigation (Sanders, JAMA); the importance of maintaining standards in clinical research despite the urgency of a pandemic has been emphasized (London, Science); timing of antiviral, immunomodulatory and anticoagulant interventions must take into account the sequential progression of illness from viral to pulmonary to inflammatory and hypercoagulable phases of illness (Liu, Circulation; Siddiqi, J Heart Lung Transpl)

**Remdesivir.** Remdesivir is a potent inhibitor of SARS-CoV-2 RNA-dependent RNA polymerase (Gordon, J Biol Chem) that causes chain termination (Yin, Science) and is active in vitro (Wang, Cell Res); effective when given prophylactically or therapeutically in a macaque model of MERS-CoV (de Wit, PNAS) and when given early in a macaque model of COVID-19 (Williamson, BioRxiv); results of compassionate use of remdesivir reported in 63 patients (Grein, NEJM): clinical improvement observed in 68%, and 57% of intubated patients were able to be extubated, but no control group or viral load measurement, and adverse events seen in 60% (including elevated LFTs); a double-blind placebo-controlled RCT in China found no benefit from remdesivir, although there was a trend toward more rapid clinical improvement in patients with symptoms ≤ 10d (Wang, Lancet)

**Chloroquine/Hydroxychloroquine/Azithromycin.** Hydroxychloroquine inhibits SARS-CoV-2 replication in vitro (Yao, Clin Infect Dis; Liu Cell Discovery); anecdotal reports of clinical benefit of chloroquine/hydroxychloroquine (Gao, Biosci Trends); a non-randomized French open-label trial reported evidence of an anti-viral effect in vivo, particularly in combination with azithromycin (Gautret, MedRxiv/Int J Antimicrob Agents); a follow-up report from the same group reported only 4% poor outcomes with <1% deaths in 1,061 patients treated early with HCQ/AZ, and no adverse cardiac outcomes, but again there was no control group (Million, Travel Med Infect Dis); in contrast, a small RCT of hydroxychloroquine failed to show a beneficial effect on viral clearance or clinical resolution (Chen, J Zhejiang Univ), while another RCT involving 62 patients observed more rapid clinical resolution and fewer patients progressing to severe illness in hydroxychloroquine recipients (Chen, MedRxiv HCQ); a subsequent larger study by the French authors has reported a good virologic and clinical outcome in 72 of 74 additional recipients of combination therapy, but without a control group (Gautret, unpublished); concerns have been raised regarding the paper by Gautret, et al. and the use of hydroxychloroquine to treat COVID-19 outside research protocols (Kim, Ann Intern Med; Hulme, MedRxiv; Yazdany, Ann Intern Med); a different French group was unable to demonstrate rapid viral clearance in 11 patients receiving the same regimen of hydroxychloroquine and azithromycin, and one patient had treatment discontinued due to QT...
prolongation (Molina, Med Mal Infect); acute renal failure is a risk factor for QTc prolongation on hydroxychloroquine/azithromycin, but baseline QTc is not (Chorin, Nat Med); based on PK studies of hydroxychloroquine in patients with COVID-19, a loading dose of 800 mg followed by 200mg BID for 7 days has been suggested (Perinel, Clin Infect Dis)

**Additional Studies of Hydroxychloroquine.** An RCT of hydroxychloroquine in China (n=75 per group) failed to detect an effect on viral clearance but found more rapid symptomatic improvement and resolution of inflammatory parameters, suggesting a possible immunomodulatory effect (Tang, MedRxiv); a retrospective French study (n=181) of patients with COVID-19 and hypoxemia found no significant reduction in ICU transfers, ARDS or mortality (Mahevas, MedRxiv)—8 patients had to discontinue hydroxychloroquine due to QTc prolongation or AV block; a retrospective of 368 VA patients found higher mortality in recipients of hydrochloroquine (27.8%) or hydrochloroquine plus azithromycin (22.1%) compared to no hydrochloroquine (11.4%), but selection bias and residual confounding cannot be excluded (Magagnoli, MedRxiv); receipt of hydroxychloroquine and/or azithromycin was not associated with lower mortality in 1438 patients hospitalized with COVID-19 in New York State, but patients were not randomized (Rosenberg, JAMA); chronic HCQ does not prevent COVID-19 or severe/fatal outcomes in patients treated for rheumatologic diseases (Mathian, Ann Rheum Dis; Gendelman, Autoimmun Rev; Konig, Ann Rheum Dis)

**Tocilizumab.** Multiple targets for immunomodulatory therapeutic intervention (Alijotas-Reig, Autoimmune Rev); possible benefits of tocilizumab (IL-6RA) or other immunomodulators in patients with severe illness or cytokine storm (Liu, MedRxiv; Xu, PNAS; Mehta, Lancet), although another uncontrolled trial of tocilizumab in 15 patients (8 of whom also received steroids) reported highly variable clinical responses with worsening in 2 and death in 3 (Luo, J Med Virol); retrospective studies have found lower mortality in tocilizumab recipients (Roumier, MedRxiv; Klopfenstein, Med Mal Infect); 2 patients treated with tocilizumab still progressed to macrophage activation syndrome, and one developed viral myocarditis (which may have resulted from immunosuppression) (Radbel, Chest); IL-6-driven immune dysregulation with macrophage activation syndrome and impaired antigen presentation is partially rescued by tocilizumab, with an increase in lymphocyte count and HLA-DR expression (Giamarellos-Bourboulis, Cell Host Microbe); a different IL-6 antagonist siltuximab was associated with a decline in CRP but variable clinical responses (Gritti, MedRxiv; Leronlimab (CC5-blocking Ab) given to patients with critical COVID-19 and elevation of IL-6/CCR5 was followed by a rapid decline in inflammatory biomarkers and reduced viral load (Patterson, MedRxiv); anakinra (IL-1 antagonist) associated with clinical improvement in 72% of patients with hyper inflammation in the setting of COVID-19 (Cavalli, Lancet Rheumatol); a pilot study suggested an improvement in inflammatory parameters and clinical outcomes in baricitinib (JAK kinase inhibitor) recipients (Cantini, J Infect)

**Lopinavir-Ritonavir.** No benefit from lopinavir-ritonavir seen in severe COVID-19 (Cao, NEJM); interferon/ribavirin/lopinavir-ritonavir superior to lopinavir-ritonavir (Hung, Lancet)
Treatment of Coagulopathy. ISTH and other societies have endorsed interim guidance on recognition and management of COVID-19-related coagulopathy (Thachil, J Thromb Haemost; Bikdeli, JACC); anticoagulation may be beneficial in patients with coagulopathy and marked D-dimer elevation (Tang 2, J Thromb Haemost); an observational study found that systemic anticoagulation correlated with improved survival in patients requiring mechanical ventilation (Paranjpe, JACC); improved oxygenation in response to therapeutic heparin (Negri, MedRxiv) or tissue plasminogen activator (tPA) (Wang, J Thromb Haemost; Poor, MedRxiv); coagulation studies may support the need for intensive anticoagulation (Panigada, J Thromb Haemost; Ranucci, J Throm Haemost; Connors, J Throm Haemost; Connors, Blood), and serious thrombotic events may occur despite anticoagulation (Helms, Intensive Care Med).

Complement Inhibition. Complement activation may contribute to thrombotic microangiopathy (Campbell, Circulation; Ciceri, Crit Care Resusc; Magro, Transl Res; Risitano, Nat Rev Immunol); anecdotal evidence that complement inhibition can improve oxygenation and reduce inflammation (Gao, MedRxiv) or Corticosteroids. Possible benefits of low-dose corticosteroids (Wu, JAMA Intern Med; Wang, MedRxiv), but this is controversial (Russell, Lancet; Shang, Lancet).

Convalescent Plasma. Possible benefit reported in an uncontrolled trial of convalescent plasma with viral neutralizing activity (Shen, JAMA); in another study, convalescent plasma with neutralizing Ab titers >1:640 was administered to 10 patients with severe COVID-19; clinical improvement was observed with falling viral load, rising lymphocyte counts, improved O2 saturation, and decreased CRP (Duan, PNAS); however, 6 patients with severe COVID-19 received convalescent plasma and cleared their virus, but 5 of them died nevertheless (Zeng, J Infect Dis); a clinical trial of convalescent serum will be initiated (Casadevall and Pirofski, J Clin Invest; Bloch J Clin Invest); although convalescent plasma is thought to work by neutralizing virus, it may also ameliorate inflammation and the hypercoagulable state of COVID-19 (Rojas, Autoimmun Rev); potential benefits of convalescent plasma include replenishing coagulation proteins and restoring ADAMTS-13 activity (Kesici, PNAS); serious adverse events are infrequent (<1%) in convalescent plasma recipients, including circulatory overload, lung injury, allergic reactions (Joyner, MedRxiv).

Angiotensin Converting Enzyme Inhibitors and Angiotensin Receptor Blockers. Continuation of ACE inhibitors/ARBs recommended (Patel, JAMA; Vaduganathan, NEJM), and ACEi/ARB are not a risk factor for COVID-19 or COVID-19-related admission, ICU admission or death (Mancia, NEJM; Mehra, NEJM; Reynolds, NEJM; de Abajo, Lancet); although hypertension is a risk factor for severe COVID-19, patients taking ACE inhibitors or angiotensin receptor blockers may be less likely to develop severe pneumonia (Feng, MedRxiv).

Miscellaneous. Avoidance of ibuprofen recommended but with little basis in evidence (Day, BMJ); receipt of hypnotics has been associated with favorable outcomes (Hu, Clin Infect Dis).
**Favipiravir.** Treatment with favipiravir, an RNA polymerase inhibitor, was superior to lopinavir-ritonavir in promoting viral clearance and radiographic improvement in an open-label non-randomized study (Cai, Engineering); patients in both arms also received inhaled IFN-α; nebulized IFN-α2b has been used in China and reported to reduce viral shedding in the respiratory tract in parallel with reduced inflammatory markers (Zhou, medRxiv)

**Arbidol.** Arbidol is a broad spectrum antiviral that blocks cell entry of enveloped viruses; a small trial found more rapid resolution of viral load and laboratory abnormalities in recipients of arbidol compared to recipients of lopinavir/ritonavir (Zhu, J Infect)

**Co-infections.** Although ventilator-associated pneumonia and other nosocomial infections may occur with prolonged hospitalization, bacterial co-infection appears to be relative infrequent; nevertheless, broad-spectrum antibiotics are frequently administered (Rawson, Clin Infect Dis); patients may appear septic but have only a 1.6% bacteremia rate, and overutilization of blood cultures can exceed lab capacity (Sepulveda, MedRxiv); invasive pulmonary aspergillosis may occur as a late and often lethal complication (Van Arkel, AJRCCM)

**Management of ARDS.** General guidance for the treatment of severe COVID-19-associated ARDS has been published (Matthay, Lancet Respir Med; Phua, Lancet Respir Med); European intensivists have stressed differences between ARDS and COVID-19, recommending the use of the lowest possible PEEP to avoid worsening lung injury (Gattinoni, AJRCCM; Gattinoni, Crit Care; Marini JAMA; Ceruti, MedRxiv; Price, Eur Heart J); severe hypoxemia with preserved lung compliance is suggested to represent a distinctive phenotype of COVID-19 resulting from pulmonary vascular pathology, possibly warranting different treatment measures (Rello, Eur Respir J); others have favored standard ARDS protocols (Ziehr, AJRCCM; Berlin, NEJM)

**IDSA Guidelines.** IDSA has published treatment guidelines regarding hydroxychloroquine/azithromycin, lopinavir/ritonavir, corticosteroids, tocilizumab and convalescent plasma (Bhimraj, Clin Infect Dis)

**PREVENTION**

**Travel Restrictions.** Travel restrictions gain time but only effective if combined with measures to reduce community transmission (Chinazzi, Science; Wells, PNAS; Kucharski, Lancet Infect Dis)

**Social Distancing.** Social distancing can be effective (Anderson, Lancet; Cowling, MedRxiv) and is more effective in reducing demand for ICU beds if instituted early (Li, MedRxiv); experience in King County indicates that strong intervention can stop the exponential rise in infections (Klein, working paper; Randhawa, JAMA); drastic social distancing interventions in Wuhan drove the effective reproductive number from 3.86 to 0.32 (Wang, MedRxiv) and less dramatically in WA/CA (Lewnard, MedRxiv); social distancing combined with visitor restriction and hand hygiene has been effective in limiting COVID-19 spread in a senior independent and assisted living setting (Roxby, MMWR)
**Beyond Social Distancing.** Sustained suppression is likely to be more effective than mitigation (Ferguson, Imperial College report); temporary non-pharmaceutical interventions may ultimately be ineffective unless accompanied by reinforcement of critical care capacity to ensure adequate care for the most severely ill patients until more definitive strategies (vaccines, new therapeutics, aggressive contact tracing and quarantine) can be implemented (Kissler, DASH); one proposal for eventual restoration of social interaction suggests sequential phases in which widespread surveillance, testing and containment capabilities are established, followed by the application of effective vaccines or therapeutics and the bolstering of public health infrastructure (Gottlieb, AEI); modeling predicts that recurrent wintertime SARS-CoV-2 outbreaks may occur, requiring repeated episodes of social distancing through 2022 (Kissler, Science); intensive control strategies require extensive diagnostic capability; delays in testing or tracing are likely to substantially reduce the effectiveness of contact tracing (Kretzschmar, MedRxiv); current gaps in diagnostic testing include widespread surveillance, screening of asymptomatic persons and monitoring shedding in convalescence (Cheng, Ann Intern Med), although it has been argued that even inaccurate tests may be useful in the surveillance setting (Ramdas, Nat Med); ~60% of the population may need to be immune for adequate herd immunity (Altmann, Lancet); a CIDRAP report describes three potential pandemic scenarios (peaks & valleys/fall peak/slow burn) (Moore, CIDRAP)

**Vaccines.** Potential vaccine platforms include RNA, DNA, recombinant proteins, viral vector-based vaccines, live attenuated virus and inactivated virus (Amanat, Immunity; Lurie, NEJM); challenges include elicitation of durable immunity and potential immune enhancement (Peeples, PNAS); an inactivated vaccine candidate has been shown to induce neutralizing Ab in mice, rats and non-human primates, neutralizes different strains, and protects macaques from challenge without evidence of antibody-dependent enhancement (Gao, Science); the Oxford ChAdOx1 adenovirus-based vaccine is protective in a macaque model (van Doremalen, BioRxiv)

**Models.** Even with social distancing, modeling studies predict excess U.S. demand at the pandemic peak in the second week of April to be 64,175 hospital beds, 17,309 ICU beds and 19,481 ventilators, with 81,114 deaths occurring over the next 4 months; IHME model (Murray, MedRxiv https://covid19.healthdata.org/united-states-of-america) has been widely used but also criticized (Jewell, Ann Intern Med)

**Health Care Workers.** Health care workers are at increased risk of infection (Pan, JAMA)—as of April 9, 2020, the CDC reported 9,282 HCWs infected in the U.S. with 723 hospitalizations, 184 ICU admissions and 27 deaths (CDC MMWR HCWs); compared to the general community, frontline HCWs are at increased risk of symptomatic COVID-19 acquisition (aHR 11.6); most positives found in contact tracing of HCWs with COVID-19 have been asymptomatic (Mandic-Rajcevic, MedRxiv) or had atypical symptoms; time required for 95% of HCWs to be cleared was 30d; many asymptotically infected HCWs may reflect community rather than hospital transmission (Treibel, Lancet); evidence suggests that PPE (masks, gloves, gowns, eye protection) and hand washing decrease HCW infection risk (Chou, Ann Intern Med); inadequate PPE increased risk, but HCWs with adequate PPE still had increased risk (Nguyen, MedRxiv);
screening of health care workers in NYC found 5% positive for SARS-CoV-2; two-thirds were asymptomatic, and prevalence was 7% higher than in non-HCW controls (Barrett, MedRxiv); random sampling of 1,032 HCWs by nasal/throat swab found 3% positive in a UK study, of whom more than half were truly asymptomatic/pauci-symptomatic, demonstrating the limitations of symptom-based preventative measures (Rivett eLife); ED, Anesthesiology and Ophthalmology residents are the specialties at highest risk for COVID-19 acquisition, followed by Surgery, Psychiatry, Medicine and Pediatrics (Breazzano, MedRxiv); the need for airborne vs droplet precautions is controversial and may be based on outdated biophysical concepts of respiratory emissions (Bourouiba, JAMA); the University of Nebraska found viral contamination of commonly used items, toilets and air samples, suggesting that airborne precautions are appropriate (Santarpia, MedRxiv); airborne SARS-CoV-2 RNA could be detected nearby patients' toilets and in areas of crowding (Liu, Nature); ~4 micron droplets generated by speaking could be detected in a closed stagnant air environment for 8-14 minutes, suggesting that SARS-CoV-2 might be transmitted by an airborne route in confined settings (Stadnytskyi, PNAS); available evidence suggests that airborne precautions will provide optimal protection for HCWs caring for patients with COVID-19 (Bahl, J Infect Dis); IDSA guidelines to protect HCWs recommend N95 or surgical masks in non aerosol-generating settings and N95 or PAPR for aerosol-generating procedures, with alternative methods in crisis settings (Lynch, IDSA Guideline)

**Face Masks.** The use of face masks lowers risk to health care workers— one study found no infections in HCWs using N95 masks to care for high-risk patients, whereas 10/215 HCWs not using masks while caring for patients considered low-risk were infected (Wang, J Hosp Infect); 20% of infected health care providers lack fever, cough or dyspnea as an initial symptom, suggesting that symptomatic screening may be less effective than universal masking of all health care providers (Chow JAMA); in view of PPE shortages, N95 respirators may be decontaminated up to 3 times with UV/H2O2 vapor or up to 2 times with dry heat and re-used (Fischer MedRxiv); surgical masks worn by individuals with infections can also reduce the risk of transmission (Leung, Nat Med); universal cloth face masks have been advocated for infection prevention in the community (Abeluck, SSRN)

**Fomites.** Fomites may contribute to transmission in the hospital environment; SARS-CoV-2 RNA has been detected in air samples near patients and on floors, printers, keyboards, computer mice, doorknobs, telephones, trash cans, sickbed handrails, medical equipment, gloves and hand sanitizer dispensers (Ye, J Infect; Guo, Emerg Infect Dis)

**EMERGENCY MANAGEMENT**

**Emergency Response.** An overview of the principles of emergency management in the State of Washington and connections to the national emergency response infrastructure has been published (Morris, Prehosp Disast Med)
This summary was compiled by Ferric C. Fang, M.D. and does not necessarily represent the views of the University of Washington or its affiliated institutions.
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