Severe acute respiratory syndrome coronavirus-2: implications for blood safety and sufficiency

Philip Kiely, Veronica C. Hoad, Clive R. Seed & Iain B. Gosbell

1Clinical Services and Research, Australian Red Cross Lifeblood, Melbourne, VIC, Australia
2Transfusion Research Unit, Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, VIC, Australia
3Western Sydney University, Penrith, NSW, Australia

Background and Objective Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) is a novel coronavirus, first identified in China at the end of 2019 and has now caused a worldwide pandemic. In this review, we provide an overview of the implications of SARS-CoV-2 for blood safety and sufficiency.

Material and Method We searched the PubMed database, the preprint sites bioRxiv and medRxiv, the websites of the World Health Organization, European Centre for Disease Prevention and Control, the US Communicable Diseases Center and monitored ProMed updates.

Results An estimated 15%–46% of SARS-CoV-2 infections are asymptomatic. The reported mean incubation period is 3 to 7 days with a range of 1–14 days. The blood phase of SARS-CoV-2 appears to be brief and low level, with RNAemia detectable in only a small proportion of patients, typically associated with more severe disease and not demonstrated to be infectious virus. An asymptomatic blood phase has not been demonstrated. Given these characteristics of SARS-CoV-2 infection and the absence of reported transfusion transmission (TT), the TT risk is currently theoretical. To mitigate any potential TT risk, but more importantly to prevent respiratory transmission in donor centres, blood centres can implement donor deferral policies based on travel, disease status or potential risk of exposure.

Conclusion The TT risk of SARS-CoV-2 appears to be low. The biggest risk to blood services in the current COVID-19 pandemic is to maintain the sufficiency of the blood supply while minimizing respiratory transmission of SARS-CoV-19 to donors and staff while donating blood.

Key words: blood safety, epidemiology, transfusion - transmissible infections, SARS-CoV-2.
COVID-19 cases globally [12]. Initially, the highest number of confirmed COVID-19 cases was reported in China. However, by mid-March, the highest number of new confirmed cases was being reported in the European Region (particularly Spain, Italy, France, Germany, the UK and, subsequently, the Russian Federation); since mid-May, the highest number of new cases has been reported in the Region of the Americas, primarily due to the US and Brazil, and the South-East Asian Region, primarily due to India [12].

In this review, we summarize what is currently known about SARS-CoV-2 and the associated disease, COVID-19, particularly those characteristics of the virus that are relevant to assessing the potential risk to blood safety. We then discuss whether the virus is potentially transfusion-transmissible and consider the impact of risk mitigation strategies that can be employed by blood centres. Additional supporting references are included in the supplementary material file.

Epidemiology of SARS-CoV-2

The origin of SARS-CoV-2 and mode of transmission to humans has not been definitively established [13–15]. Sequence homology studies indicate that SARS-CoV-2 may have originated from a bat coronavirus and transmitted to humans via an intermediate host [7,14,16,17].

Many of the earliest, although not all, reported cases of SARS-CoV-2 (prior to 1 January 2020) were directly or indirectly associated with a seafood/animal market in Wuhan, which now appears to have been due to human-to-human transmission [18,19]. Subsequently, the rapid geographical spread and increase in case numbers of SARS-CoV-2 in China and beyond has demonstrated that sustained person-to-person transmission is now the primary mode of transmission [3,20]. COVID-19 cases have been reported in clusters typified by people coming into close contact in confined spaces, often with the identification of superspreaders [21–23]. These include households, public gatherings, conferences, healthcare facilities, religious gatherings and cruise ships [3,24–26]. For example, the Diamond Princess cruise ship off Japan resulted in 712 confirmed cases [12] and there were 600 confirmed cases on the Ruby Princess in Sydney, Australia [27].

Evidence indicates that the predominant mode of human-to-human SARS-CoV-2 transmission is via airborne droplets. SARS-CoV-2 has been demonstrated to infect cells of the upper respiratory tract and isolated from a variety of human respiratory fluids including saliva, bronchoalveolar lavage fluid, nasopharyngeal and throat swabs [28–30]. Transmission by aerosol particles is not a major mode of transmission [31–33]. Under laboratory conditions, it has been demonstrated that infectious virus is stable for a limited time on surfaces (fomites) and in generated aerosols contaminated with cultured virus. [34,35]. Studies of isolated COVID-19 patients and hospital wards have reported natural SARS-CoV-2 RNA contamination of commonly used items, surfaces, outdoor environment and air samples, suggesting the contamination of surfaces by airborne droplets [33,36–38]. However, these studies either did not detect or did not test for infectious virus and therefore the importance of fomites in the transmission of SARS-CoV-2 is not clear.

There is evidence that SARS-CoV-2 is transmissible by infected asymptomatic and pre-symptomatic individuals [39,40]. A number of transmission clusters with evidence of possible transmission from pre-symptomatic individuals in close contact have been reported [41–44]. Several studies have reported serial intervals (time from symptom onset in a primary case to symptom onset in a secondary case) shorter than the incubation period, suggesting asymptomatic and pre-symptomatic transmission [45,46]. In addition, SARS-CoV-2 RNA has been detected in respiratory swabs and faeces from asymptomatic individuals [47,48].

There is currently no evidence for intrauterine transmission of SARS-CoV-2 [49,50] or vertical transmission to newborns [51]. A small number of cases of SARS-CoV-2 RNA detection in the breast milk of infected nursing mothers have been reported [52–54]. However, the detection of infectious virus in breastmilk or transmission by breastfeeding has not been reported, consistent with MERS-CoV and SARS-CoV. There is no evidence of sexual transmission of SARS-CoV-2 [51,55]. One study has reported evidence that SARS-CoV-2 may be transmissible by the ocular conjunctival route under some circumstances, however this has been questioned [56–58]. SARS-CoV-2 has been shown to infect cells in the ileum and colon, and infectious virus has been isolated from rectal swabs and stool, indicating that the digestive system may also be a route of infection and faecal transmission may be possible [59–62].

COVID-19: disease characteristics

Directly estimating the proportion of asymptomatic SARS-CoV-2 infections in the general population is not currently possible as the total number of infections is unknown, and awaits the publication of reliable seroprevalence studies. In addition, reported estimates of the proportion of asymptomatic infections vary due to the differences in methodology and the epidemiology of the study population. Three studies have reported estimates based on specific study groups in which all individual
were tested for SARS-CoV-2 RNA (but not serologically) [63–65]. The estimated percentage of asymptomatic infections varied between a mean of 30.8% (95% CI: 7.7–53.8%) and a median of 34.6% (95% credible interval: 29.4%–39.8%). Subsequently, there have been a number of additional studies and meta-analyses, with estimates varying from 15% (95% CI: 12–18%) to 46% (95% CI: 18–73%) [66–69].

The incubation period for SARS-CoV-2 infection has been modelled by several studies, most showing close agreement with the estimated means/medians ranging from 3–0 days (IQR: 2–0–6.0) to 7–5 days (95% CI: 4.1–10.9) [70–72]. There was some variation between studies for the estimated ranges of the incubation period but most were within the range of 2 to 11 days and almost all infections developed symptoms by day 14. These estimates have been supported by several subsequent meta-analyses which estimated mean values between 4.24 days (95% CI: 3.03–5.44) and 6.93 days (95% CI: 6.11–7.75) [68,73–75].

Studies from several countries have demonstrated that the majority of reported confirmed COVID-19 cases in the general population are mild/moderate [76–79]. For example, a large study of reported confirmed cases in China (n = 44 672) reported that 81% of cases were mild infections, 14% were severe, 5% were critical and 2.3% of cases died [3,20]. The median age of COVID-19 patients varies between countries due to differences in epidemiology and the stage of the pandemic. In initial reports, based primarily on Chinese studies, the median age of patients varied between 47 and 56 years and a majority were males [53.4–73%] [18,80]. Subsequently, studies from several countries have reported the mean age of COVID-19 patients, varying from 39 years (Brazil) to 72 years (US) [77,81–84]. For most countries, the average age of patients was >60 years. Although there is some variation between studies, typically the most common symptoms were fever (83–98%), cough (59–81%), myalgia/fatigue (44–70%) and breathing difficulties (31–55%). Less common symptoms included confusion, headache, sore throat, rhinorrhea, congestion, expectoration, cutaneous symptoms (including chills-like lesions), cardiovascular complications, gastrointestinal symptoms (diarrhoea, anorexia, nausea and vomiting) and neurological symptoms. People of older age, male gender, smokers or those with underlying disease, particularly cardiovascular disease, chronic respiratory disease, hypertension, diabetes, chronic kidney disease and Down’s syndrome, are at a higher risk of developing severe symptoms [3,20,77,83–88]. Patients with severe disease may also have neurologic symptoms including acute cerebrovascular diseases, impaired consciousness, seizures, meningoencephalitis, Guillain–Barré syndrome and skeletal muscle injury [89,90]. More recently, acute temporary loss or impaired taste, olfactory and chemesthesia function have been recognized as common (>60% in some studies) and specific early symptoms of SARS-CoV-2 infection [91–93]. Compared to adults, it appears children have a higher proportion of asymptomatic infections, milder symptomatic infections, a lower fatality rate and possibly a longer incubation period [94–96]. A syndrome, which has Kawasaki disease-like symptoms and referred to as multisystem inflammatory syndrome in children (MIS-C) or paediatric inflammatory multisystem syndrome – temporally associated with SARS-CoV-1 (PIMS-TS), has been reported in children with COVID-19. The syndrome has a wide range of presenting symptoms, from fever, inflammation and gastrointestinal symptoms to myocardial injury, shock and development of coronary artery aneurysms [97–100].

While the fatality rate among reported confirmed cases varies substantially between regions, the risk factors for death are consistent, namely older age, male gender and comorbidities [101–103]. The Chinese study noted above reported no fatalities in patients under 10 and 0.2% fatality rate in those between 20 and 40, but increasing to 8.0% for those 60–69 and 14.8% for those 80 or over [20,102], and similar findings have been reported by other studies [102–107]. The same Chinese study found that male patients were overall approximately 1.6 times as likely to die than female patients (2.8% vs. 1.7%), a finding also reported by other studies [102,105]. Compared to all reported COVID-19 cases, patients with a fatal outcome have higher rates of comorbidities including hypertension, diabetes, chronic vascular disease and chronic lung disease [102,104,105]. It is currently not possible to accurately estimate the total number of SARS-CoV-2 infections due to asymptomatic infections which would typically not be reported nor diagnosed, underreporting of symptomatic cases and lack of attribution of COVID-19 as cause of death [108–110]. As a consequence, it is not possible at present to estimate the infection fatality rate (IFR) for all infections (reported and unreported). However, a number of studies and meta-analyses have modelled the IFR, taking into account the proportion of unreported infections. While estimates of the mean overall IFR vary from 0% to approximately 5%, most studies reported values between 0.2% and 2% [68,111–114].

Data on SARS-CoV-2 RNA detection in blood (RNAemia) are limited, and the blood phase of SARS-CoV-2 infection has not been well defined. A number of studies have shown that only a small proportion of COVID-19 patients had detectable RNAemia, although most had detectable viral RNA in respiratory swabs [18,59,115–120]. The RNAemia period appears to be brief, low level and typically associated with more severe disease.
symptoms. There has been one report demonstrating that SARS-CoV-2 RNA detected in the blood of patients was not associated with infectious virus [121]. A single case study of a patient with an extended period (approximately 40 days post-symptom onset) of RNAemia has been reported [122]. However, the RNA levels were low, anti-SARS-CoV-2 IgG was detectable and the presence of infectious virus was not demonstrated. There have also been reports of SARS-CoV-2 detection in peripheral blood mononuclear cells (PBMCs) [123] and platelets [124]. However, this appears to be rare, the levels of RNA in these cases were low and the presence of infectious virus was not demonstrated. In summary, RNAemia is not detectable in most COVID-19 patients, is low level, brief and may not represent infectious virus.

A number of studies have reported SARS-CoV-2 antibody seroconversion times relative to time of symptom onset with mean/median times varying from 5–11 days for total antibody, 8–14 days for IgM and 10–14 days for IgG [125–130]. Neutralizing antibodies become detectable within 10–15 days of symptom onset and correlate with total antibody levels [129]. Severe COVID-19 is associated with higher levels of antibody compared to mild cases [130,131]. Long-term serological studies are not yet possible, but initial studies have indicated that IgM declines from about 2 weeks post-symptom onset. One study reported the loss of detectable IgG within 2 months [132], but most reports indicate that while IgG levels decline after approximately 2 months, levels remain relatively high for several months [131,133,134]. Assuming that detectable RNAemia represented infectious virus, it would be expected that blood would no longer be infectious once rising titres of IgG or total antibody become detectable and viral RNA levels declined. This is indicated by a study of COVID-19 patients who were plasma RT-PCR-positive. Using a fitted curve, the plasma RT-PCR-positive rate in samples from the patients was > 90% for samples taken 1–3 days post-symptom onset but declined to <50% by 14 days [127].

Implications for safety and sufficiency of the blood supply

Broadly, emerging infectious disease (EID) pathogens can be classified into two categories. Firstly, those that are vector-borne, with limited or no human-to-human transmission. Secondly, those that are spread predominately human-to-human, such as respiratory viruses. Both categories of pathogen may impact blood safety due to the potential transfusion-transmission risk and the sufficiency of the blood supply due to infected donors/staff being unwell and unable to donate/attend work, or the loss of donors due to deferrals or social disruption. Pathogens that are predominately transmitted human-to-human may also impact sufficiency of supply due to donors being reluctant to attend donor centres out of fear of being infected. In this section, we will assess the likelihood that SARS-CoV-2 can be transmitted by transfusion and then summarize some of the strategies that blood centres can use to mitigate any potential risk to blood safety and supply.

Transfusion-transmissibility

The following criteria have been used to assess if an EID pathogen is a potential risk to blood safety: (1) able to establish infection in humans and spread within populations, (2) infection includes an asymptomatic blood phase, (3) able to survive during blood processing and storage, (4) transmissible by the intravenous route and (5) associated with a clinically apparent disease in at least a proportion of recipients [135].

As noted in the first part of this review, it is now clear that SARS-CoV-2 can establish infection in humans and cause disease (COVID-19), which may result in severe symptoms and death, and also spread efficiently from human-to-human within populations. Although SARS-CoV-2 RNA has been detected in respiratory swabs of asymptomatic patients [64,136], it has not been determined if SARS-CoV-2 infection includes an asymptomatic blood phase, either the pre-symptomatic period for infections that become symptomatic or during the course of infection in cases that do not develop symptoms. However, the absence of reported cases of SARS-CoV-2 RNA detection in the blood of asymptically infected individuals may be due to infrequent testing of blood as respiratory swabs are primarily used for laboratory diagnosis, most cases referred for laboratory testing are symptomatic and the potential viraemic period is probably brief and low level. The relative viral loads in the different constituents of blood, and whether viable SARS-CoV-2 is able to survive during blood processing and storage (for fresh products) has also not been determined. Similar to other human coronaviruses (including SARS-CoV and MERS-CoV), transfusion transmission of SARS-CoV-2 has not been reported [137–140], suggesting that transfusion transmission of coronaviruses is rare, if it occurs at all. However, it is acknowledged that SARS-CoV-2 has only recently been identified and therefore future reporting of transfusion-transmitted cases cannot be excluded.

Several studies have reported results of SARS-CoV-2 RNA testing of blood donors. A study of seven Korean donors, identified as COVID-19 cases post-donation, failed to detect SARS-CoV-2 RNA in repository samples from all donors [141]. In addition, platelets and red cells from
some of these donors were transfused, but no recipients had developed COVID-19 symptoms between 19–29 days post-transfusion. A study of blood donor screening/retrospective testing at the Wuhan Blood Center reported detectable RNAemia in four donors [142]. However, these results should be interpreted with some caution. The RT-PCR results showed weak signals, indicating low levels of RNA and the possibility of false-positive results or assay contamination cannot be excluded. A case of a patient with very severe aplastic anaemia who received an apheresis platelet transfusion from a donor diagnosed with COVID-19 three days after donation has been reported [143]. There was no evidence of transfusion transmission as the recipient tested negative on follow-up testing and did develop symptoms. A report of SARS-CoV-2 RNA blood donor screening and retrospective testing in Wuhan on donor samples collected during January found 4 of 7425 donors were RNA-positive. In all cases, RNA was present at low levels and infectious virus was not confirmed [144]. A subsequent report of SARS-CoV-2 RNA screening of 94 342 blood donations in Hubei Province between 9 February and 30 April 2020 found no RNA-positive donations [145]. However, it was noted that this testing period was immediately after the height of the COVID-19 outbreak in Hubei. A Chinese study has estimated the number of donors who may have donated while in the COVID-19 incubation period for the period through to the 17 March [146]. Although the number of potentially infected donors in the incubation period was low (4-05 for the whole of China), it should also be noted that only a small proportion of window period cases would likely have detectable viral RNA and, as noted, it has not been established that infectious virus circulates in the blood.

Risk mitigation strategies

As noted, a majority of SARS-CoV-2 infections probably result in symptomatic infections with a relatively short incubation period. Donors with symptomatic infection, if presenting to donate, would be deferred from donating. In addition, blood donors should be encouraged to notify the blood centre if they develop symptoms post-donation, such as fever in the two days post-donation or sudden taste or smell dysfunction, a strategy that would partly mitigate any theoretical transfusion-transmission risk associated with donors in the incubation period but more importantly, allows contact tracing to occur if required.

For countries that have either not reported SARS-CoV-2 cases or have small clusters of human-to-human transmission (i.e. no sustained human-to-human transmission), the potential SARS-CoV-2 transfusion-transmission risk can be reduced by travel-related donor deferrals, especially in the initial phase of the epidemic when most cases are imported. Blood centres in these countries can implement a deferral, either for donors returning from countries assessed as high risk for SARS-CoV-2 infection or, given that most countries are now affected by SARS-CoV-2, all donors returning from overseas. As the epidemic progresses in a particular geographical region with sustained widespread local transmission, travel-related deferrals will be less effective in mitigating transfusion-transmission risk, especially if government closes the borders to overseas travellers and imposes a period of isolation for returning citizens [147]. A deferral for donors infected with or potentially exposed to SARS-CoV-2 can be implemented to further reduce any potential transfusion-transmission risk. For example, the WHO, US FDA and Asia Pacific Blood Network (ABPN) guidelines recommend a deferral period of 28 days for donors after possible exposure and the deferral of recovering confirmed cases of SARS-CoV-2 for at least 28 days after symptom resolution [148–150]. For convalescent plasma donors, the US FDA has recommended that a period of at least 14 days after resolution before the donation [151]. Other potential risk mitigation strategies that can be used to reduce the transfusion-transmission risk of emerging infectious diseases include pathogen reduction technologies (PRTs), donor laboratory screening and quarantine of blood components with delayed release if there is no subsequent illness reported by the donor [152–154]. Commercial PRTs are effective for MERS-CoV and SARS-CoV and at least one is effective for SARS-CoV-2 [155–157]. However, for countries that have not already implemented PRTs, it is unlikely to be a cost-effective strategy, particularly as transfusion transmission of SARS-CoV-2 has not been reported [139,158]. For each country, the implementation of blood donor screening for SARS-CoV-2 would require a validated assay approved by that country’s regulator and, at present, this is not an option for most countries. In addition, given the low risk, if any, of transmitting SARS-CoV-2 by transfusion, implementing a donor screening assay would not be cost-effective. Quarantining of components would be difficult to implement operationally and, particularly if there is widespread transmission of SARS-CoV-2, could potentially impact the sufficiency of supply. In addition, quarantining platelets would not be feasible due to the short shelf life.

Sufficiency of supply and proportionate response

The response by blood centres to outbreaks and epidemics should be proportionate to the level of risk to both recipients and sufficiency of supply [150,159]. Decisions about implementing donor travel deferrals need to balance the safety and sufficiency of the blood supply. For example,
the deferral of donors will result in the loss of product in the short term and, potentially in the longer term, donors. The deferral of blood donors can have adverse psychological impacts on donors and negatively impact future donation intention [160,161]. In addition, it is important that both blood centres and government health departments carefully manage their response to infectious disease outbreaks, taking care not to create undue concern among donors and the general population as donors may be reluctant to attend donor centres due to a fear of being infected and/or reluctance to travel due to restrictions [162–165]. Therefore, it is important for blood centres to take appropriate measures to mitigate the risk of SARS-CoV-2 transmission in donor centres, as this will reassure donors and minimize the risk of transmission to staff. A potential measure to maintain donor numbers is to relax existing donor deferrals, where it is demonstrably safe to do so. For example, the US FDA has recently recommended a relaxation of donor deferrals relating to sexual activity [166]. Attracting and selecting suitable donors is an important challenge, given that convalescent plasma [167–169], intravenous immunoglobulin (IVIG) and hyperimmune globulin [170,171] are being investigated as potential treatment options for COVID-19.

Conclusions

For countries without a substantial number of reported cases or where most cases are imported, the potential transfusion-transmission risk associated with SARS-CoV-2 could be reduced by the implementation of deferral policies relating to potential geographical exposure, a history of SARS-CoV-2 infection or potential local exposure to SARS-CoV-2 cases. For countries with widespread and sustained local transmission, in addition to the deferral of confirmed cases and those potentially exposed, PRT may be an option to reduce the transfusion-transmission risk, but each country would need to perform its own risk assessment to determine the cost-effectiveness. However, based on current knowledge of SARS-CoV-2 infection and the absence of reported transfusion transmission of coronaviruses, the risk of transmitting SARS-CoV-2 by transfusion appears to be low or may not occur at all. If it does occur, the risk is certainly substantially lower than the respiratory route. Accordingly, the biggest risk to blood services in the current COVID-19 pandemic is to maintain the sufficiency of the blood supply, including adequate provision of plasma, while minimizing respiratory transmission of SARS-CoV-19 to donors and staff while donating blood.

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Conflict of interests

The authors declare no conflict of interests.

References

1 World Health Organization: Emergencies preparedness, response. Pneumonia of unknown cause - China. Disease outbreak news, 5 January 2020. https://www.who.int/csr/don/05-january-2020-pneumonia-of-unknown-cause-china/en/ [Last accessed 25 August 2020]
2 European Centre for Disease Prevention and Control: Cluster of pneumonia cases caused by a novel coronavirus, Wuhan, China; – 17 January 2020. Stockholm: ECDC; 2020. https://www.ecdc.europa.eu/sites/default/files/documents/Assessment%20-%20Pneumonia%20Wuhan%20China%2020200117%20%20Jan%202020200.pdf [Last accessed Last accessed 25 August 2020]
3 Wu Z, McGoogan JM: Characteristics of and important lessons from the coronavirus disease: (COVID-19) Outbreak in China: summary of a report of 72314 cases from the Chinese Center for Disease Control and Prevention. JAMA 2020;323:1239–1242
4 Zhou P, Yang X-L, Wang X-G, et al.: Discovery of a novel coronavirus associated with the recent pneumonia outbreak in humans and its potential bat origin. bioRxiv 2020;2020.01.22.914952
5 Wu F, Zhao S, Yu B, et al.: A new coronavirus associated with human respiratory disease in China. Nature 2020;579:265–269
6 Gorbalenya AE: Severe acute respiratory syndrome-related coronavirus – The species and its viruses, a statement of the Coronavirus Study Group. bioRxiv 2020; 2020.02.07.937862
7 Lu R, Zhao X, Li J, et al.: Genomic characterisation and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. Lancet 2020; 395:565–574
8 Kasibhatla SM, Kinikar M, Limaye S, et al.: Understanding evolution of SARS-CoV-2: A perspective from analysis of genetic diversity of RdRp gene. J Med Virol 2020. https://doi.org/10.1002/jmv.25909
9 World Health Organization: Coronavirus disease 2019. Technical guidance. Naming the coronavirus disease (COVID-19) and the virus that causes
it. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/naming-the-coronavirus-disease-(covid-19)-and-the-virus-that-causes-it [Last accessed 25 August 2020]

10 World Health Organization: WHO Director-General’s statement on IHR Emergency Committee on Novel Coronavirus (2019-nCoV), 30 January 2020. https://www.who.int/dg/speeches/detail/who-director-general-s-statement-on-ihr-emergency-committee-on-novel-coronavirus-(2019-ncov) [Last accessed 25 August 2020]

11 World Health Organization: WHO Director-General’s opening remarks at the media briefing on COVID-19 – 11 March 2020. https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19–11-march-2020 [Last accessed 25 August 2020]

12 World Health Organization: Coronavirus disease (COVID-19). WHO Coronavirus Disease (COVID-19) Dashboard. https://covid19.who.int/ [Last accessed 17 September 2020]

13 Andersen KG, Rambaut A, Lipkin WI, et al.: The proximal origin of SARS-CoV-2. Nat Med 2020; 26:450–452

14 Li X, Zai J, Zhao Q, et al.: Evolutionary history, potential intermediate animal host, and cross-species analyses of SARS-CoV-2. J Med Virol 2020; 92:602–611

15 Han G-Z: Pangolins Harbor SARS-CoV-2-related coronaviruses. Trends Microbiol 2020; 28:515–517

16 Lopes LR, de Mattos Cardillo G, Paiva PB: Molecular evolution and phylogenetic analysis of SARS-CoV-2 and hosts ACE2 protein suggest Malayan pangolin as intermediary host. Braz J Microbiol 2020; 1–7. [Epub ahead of print]

17 Boni MF, Lemey P, Jiang X, et al.: Evolutionary origins of the SARS-CoV-2 sarbecovirus lineage responsible for the COVID-19 pandemic. Nat Microbiol 2020. https://doi.org/10.1038/s41556-020-0771-4

18 Huang C, Wang Y, Li X, et al.: Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020; 395:497–506

19 Li Q, Guan X, Wu P, et al.: Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med 2020; 382:1199–1207

20 Team TNCPERE: Vital surveillances: the epidemiological characteristics of an outbreak of 2019: novel coronavirus diseases (COVID-19) — China, 2020. China CDC Weekly 2020; 2:113–122

21 Xu XK, Liu XF, Wu Y, et al.: Reconstruction of transmission pairs for novel coronavirus disease, (COVID-19) in mainland China: estimation of super-spreading events, serial interval, and hazard of infection. Clin Infect Dis 2020. https://doi.org/10.1093/cid/ciaa790

22 Lau MS, Grenfell B, Nelson K, et al.: Characterizing super-spreading events and age-specific infectivity of COVID-19 transmission in Georgia, USA. medRxiv 2020; 2020.06.20.20130476

23 Pope A, Genger J-W, Nicholson M, et al.: Mutational dynamics and transmission properties of SARS-CoV-2 superspreading events in Austria. bioRxiv 2020; 2020.07.15.204339

24 Jiaye L, Xuejiao L, Shen Q, et al.: Community transmission of severe acute respiratory syndrome coronavirus 2, Shenzhen, China, 2020. Emerg Infect Dis 2020; 26:1320–1323

25 KCDC:Press release https://www.cdc.go.kr/board/board.es?mid=a01300000003 [Last accessed 25 August 2020]

26 Integrated surveillances of COVID-19 in Italy, 10 April 2020. https://www.epicentro.iss.it/en/coronavirus/bollettinoInfoGráfica_10aprilie%20ENG.pdf [Last accessed 25 August 2020]

27 Australian Broadcasting Commission (ABC): Ruby Princess coronavirus deaths to be subject of criminal investigation by NSW Police homicide squad. 5 April 2020. https://www.abc.net.au/news/2020-04-05/ruby-prince-ss-cruise-coronavirus-deaths-investigated-nsw-police/12123212 [Last accessed 25 August 2020]

28 Yang Y, Yang M, Shen C, et al.: Evaluating the accuracy of different respiratory specimens in the laboratory diagnosis and monitoring the viral shedding of 2019-nCoV infections. medRxiv 2020; 2020.02.11.20021493

29 Bwire GM, Majigo MV, Njoro BJ, et al.: Detection profile of SARS-CoV-2 using RT-PCR in different types of clinical specimens: A systematic review and meta-analysis. J Med Virol 2020. https://doi.org/10.1002/jmv.26349

30 Weiss A, Jellingsø M, Sommer MOA: Spatial and temporal dynamics of SARS-CoV-2 in COVID-19 patients: a systematic review and meta-analysis. EBioMedicine 2020; 58:102916

31 Klompas M, Baker MA, Rhee C: Airborne transmission of SARS-CoV-2: theoretical considerations and available evidence. JAMA 2020; 324:441–42

32 World Health Organization: Transmission of SARS-CoV-2: implications for infection prevention precautions. Scientific brief, 09 July 2020. https://www.who.int/publications/i/item/2020.03.29.20046557

33 Zhou J, Otter JA, Price JR, et al.: Investigating SARS-CoV-2 surface and air contamination in an acute healthcare setting during the peak of the COVID-19 pandemic in London. Clin Infect Dis 2020. https://doi.org/10.1093/cid/ciaa905

34 van Doremalen N, Bushmaker T, Morris DH, et al.: Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med 2020; 382:1564–1567.

35 Pastirno B, Tourte F, Gilles M, et al.: Prolonged infectivity of SARS-CoV-2 in fomites. Emerg Infect Dis 2020; 26:2256–2257. https://doi.org/10.3201/eid2609.201788

36 Chia FY, Coleman KK, Tan YK, et al.: Detection of air and surface contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in hospital rooms of infected patients. medRxiv 2020; 2020.01.29.20046557

37 Guo ZD, Wang ZY, Zhang SF, et al.: Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in hospital wards, Wuhan, China, 2020. Emerg Infect Dis 2020; 26:1583–1591

38 Jiang FC, Jiang XL, Wang ZG, et al.: Detection of Severe Acute Respiratory
Syndrome Coronavirus 2 RNA on surfaces in quarantine rooms. Emerg Infect Dis 2020; 26:2162–2164. [https://doi.org/10.3201/eid2609.201435]

39 Moghadas SM, Fitzpatrick MC, Sah P, et al.: The implications of silent transmission for the control of COVID-19 outbreaks. Proc Natl Acad Sci 2020; 117:17513–17515

40 Savvides C, Siegel R: Asymptomatic and presymptomatic transmission of SARS-CoV-2: a systematic review. medRxiv 2020; 2020.06.11.20129072

41 Zhen-Dong T, An T, Ke-Feng L, et al.: Potential presymptomatic transmission of SARS-CoV-2, Zhejiang Province, China. 2020. Emerg Infect Dis 2020; 26:1052–1054

42 Li P, Fu J-B, Li K-F, et al.: Transmission of COVID-19 in the terminal stage of incubation period: a familial cluster. Int J Infect Dis 2020; 92:452–453

43 Yu P, Zhu J, Zhang Z, et al.: A familial cluster of infection associated with the 2019 novel coronavirus indicating potential person-to-person transmission during the incubation period. J Infect Dis 2020; 221:1757–1761

44 Zhang W, Cheng W, Luo L, et al.: Secondary Transmission of Coronavirus disease from presymptomatic persons, China. Emerg Infect Dis 2020; 26:1924–1926

45 Tindale L, Coome M, Stockdale JE, et al.: Transmission interval estimates suggest pre-symptomatic spread of COVID-19. medRxiv 2020; 2020.03.03.20029983

46 Nishiura H, Linton NM, Akhmetzhanov AR: Serial interval of novel coronavirus (COVID-19) infections. Int J Infect Dis 2020; 24:154–155

47 Hu Z, Song C, Xu C, et al.: Clinical characteristics of 24 asymptomatic infections with COVID-19 screened among close contacts in Nanjing, China. medRxiv 2020; 2020.02.20.20025619

48 Lan L, Xu D, Ye G, et al.: Positive RT-PCR test results in patients recovered from COVID-19. JAMA 2020; 323:1502

49 Chen H, Guo J, Wang C, et al.: Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records. Lancet 2020; 395:809–815

50 Schwartz DA: Vertical transmission of severe acute respiratory syndrome coronavirus 2 from the mother to the infant. JAMA Pediatr 2020. [https://doi.org/10.1001/jamapediatrics.2020.2135]

51 Qiu L, Liu X, Xiao M, et al.: SARS-CoV-2 is not detectable in the vaginal fluid of women with severe COVID-19 infection. Clin Infect Dis 2020; 15:913–917

52 Grofl R, Conzelmann C, Müller J, et al.: Detection of SARS-CoV-2 in human breast milk. medRxiv 2020; 2020.04.28.20075523

53 Tam PCK, Ly KM, Kernich ML: Detectable severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in human breast milk of a mildly symptomatic patient with coronavirus disease 2019 (COVID-19). Clin Infect Dis 2020. [https://doi.org/10.1093/cid/ciaa673]

54 Chambers CD, Krogestad P, Bertrand K, et al.: Evaluation of SARS-CoV-2 in breastmilk from 18 infected women. medRxiv 2020; 2020.06.12.20127944

55 Cui P, Chen Z, Wang T, et al.: Clinical features and sexual transmission potential of SARS-CoV-2 infected female patients: a descriptive study in Wuhan, China. medRxiv 2020; 2020.02.26.20028225

56 Deng W, Bao L, Gao H, et al.: Rhesus macaques can be effectively infected with SARS-CoV-2 via ocular conjunctival route. bioRxiv 2020; 2020.03.13.990036

57 Liu Z, Sun CB: Conjunctiva is not a receptor ACE2 in the human conjunctiva. J Med Virol 2020. [https://doi.org/10.1002/jmv.25859]

58 Lange C, Wolf J, Auw-Haedrich C, et al.: Expression of the COVID-19 receptor ACE2 in the human conjunctiva. J Med Virol 2020. [https://doi.org/10.1002/jmv.25981]

59 Zhang W, Du R-H, Li B, et al.: Molecular and serological investigation of 2019-nCoV infected patients: implication of multiple shedding routes. Emerg Microbes Infect 2020; 9:386–389

60 Amiri AN: Potential fecal transmission of SARS-CoV-2: Current evidence and implications for public health. Int J Infect Dis 2020; 95:363–370

61 Sehni P, Cheruiyot I: Presence of live SARS-CoV-2 Virus in feces of coronavirus disease 2019 (COVID-19) patients: a rapid review. medRxiv 2020; 2020.06.27.20105429

62 Jeong HW, Kim S-M, Kim H-S, et al.: Viable SARS-CoV-2 in various specimens from COVID-19 patients. Clin Microbiol Infect 2020. [https://doi.org/10.1016/j.cmi.2020.07.020]

63 Nishiura H, Kobayashi T, Miyama T, et al.: Estimation of the asymptomatic ratio of novel coronavirus infections (COVID-19). Int J Infect Dis 2020; 94:154–155

64 Mizumoto K, Kagaya K, Zarebski A, et al.: Estimating the asymptomatic ratio of 2019 novel coronavirus onboard the Princess Cruises ship 2020. medRxiv 2020; 2020.02.20.20002566

65 Tabata S, Imai K, Kawano S, et al.: The clinical characteristics of COVID-19: a retrospective analysis of 104 patients from the outbreak on board the Diamond Princess cruise ship in Japan. medRxiv 2020.03.18.20038125

66 Byambahuron O, Cardona M, Bell K, et al.: Estimating the extent of true asymptomatic COVID-19 and its potential for community transmission: systematic review and meta-analysis. medRxiv 2020; 2020.10.10.20097543

67 Buitrago-García DC, Egli-Gandy D, Counotte MJ, et al.: The role of asymptomatic SARS-CoV-2 infections: rapid living systematic review and meta-analysis. medRxiv 2020; 2020.04.25.20079103

68 He W, Yi GY, Zhu Y: Estimation of the basic reproduction number, average incubation time, asymptomatic infection rate, and case fatality rate for COVID-19: Meta-analysis and sensitivity analysis. J Med Virol 2020. [https://doi.org/10.1002/jmv.26041]

69 Oran ES: Potential fecal transmission of SARS-CoV-2: Current evidence and implications for public health. Int J Infect Dis 2020; 95:363–370

70 Sehni P, Cheruiyot I: Presence of live SARS-CoV-2 Virus in feces of coronavirus disease 2019 (COVID-19) patients: a rapid review. medRxiv 2020; 2020.06.27.20105429

71 Jeong HW, Kim S-M, Kim H-S, et al.: Viable SARS-CoV-2 in various specimens from COVID-19 patients. Clin Microbiol Infect 2020. [https://doi.org/10.1016/j.cmi.2020.07.020]
70 Backer JA, Klinkenberg D, Wallinga J: Incubation period of 2019 novel coronavirus (2019-nCoV) infections among travellers from Wuhan, China, 20–28 January 2020. Euro Surveill 2020; 25:2000062

71 Linton NM, Kobayashi T, Yang Y, et al.: Incubation Period and Other Epidemiological Characteristics of 2019 Novel Coronavirus Infections with Right Truncation: a Statistical Analysis of Publicly Available Case Data. medRxiv 2020; 2020.01.26.20018754

72 Lauer SA, Grantz KH, Bi Q, et al.: The Incubation Period of Coronavirus Disease 2019 (COVID-19) from Publicly Reported Confirmed Cases: Estimation and Application. Ann Intern Med 2020; 172:577–582

73 Pak D, Langohr K, Ning J, et al.: Modeling the Coronavirus Disease 2019 Incubation Period: Impact on Quarantine Policy. medRxiv 2020; 2020.06.27.20141002

74 Ejima K, Kim KS, Ludema C, et al.: Estimation of the Incubation Period of COVID-19 Using Viral Load Data. medRxiv 2020; 2020.06.16.20132985

75 Wei Y, Wei L, Liu Y, et al.: A Systematic Review and Meta-analysis Reveals Long and Dispersive Incubation Period of COVID-19. medRxiv 2020; 2020.06.20.20134387

76 Zhu J, Ji P, Pang J, et al.: Clinical Characteristics of 3062 COVID-19 Patients: a Meta-analysis. J Med Virol 2020. https://doi.org/10.1002/jmv.25884

77 Docherty AB, Harrison EM, Green CA, et al.: Features of 16,749 Hospitalised UK Patients with COVID-19 using the ISARIC WHO Clinical Characterisation Protocol. medRxiv 2020; 2020.04.23.20076042

78 Heydari K, Rismantab S, Shamshirian A, et al.: Clinical and Paraclinical Characteristics of COVID-19 Patients: a Systematic Review and Meta-analysis. medRxiv 2020; 2020.03.26.20044057

79 Pormohammad A, Ghorbani S, Baradaran B, et al.: Clinical Characteristics, Laboratory Findings, Radiographic Signs and Outcomes of 61,742 Patients with Confirmed COVID-19 Infection: a Systematic Review and Meta-analysis. Microb Pathog 2020; 147:104390

80 Fang Z, Yi F, Wu K, et al.: Clinical Characteristics of Coronavirus Pneumonia 2019 (COVID-19): an Updated Systematic Review. medRxiv 2020; 2020.03.07.20032573

81 Giorgi Rossi P, Ferroni E, Spilia Alegiani S, et al.: Survival of Hospitalized COVID-19 Patients in Northern Italy: a Population-based Cohort Study by the ITA-COVID19 Network. medRxiv 2020; 2020.05.15.20103119

82 Kalyanaraman Marcello R, Dolle J, Grami S, et al.: Characteristics and Outcomes of COVID-19 Patients in New York City’s Public Hospital System. medRxiv 2020; 2020.05.29.20086645

83 Khawaja AP, Warwick AN, Hysy PG, et al.: Associations with COVID-19 Hospitalisation Amongst 406,793 Adults: the UK Biobank Prospective Cohort Study. medRxiv 2020; 2020.05.06.20092957

84 Souza WMD, Buss LF, da Silva Candido D, et al.: Epidemiological and Clinical Characteristics of the Early Phase of the COVID-19 Epidemic in Brazil. medRxiv 2020; 2020.04.25.20077396

85 Yang Y, Lu Q, Liu M, et al.: Epidemiological and Clinical Features of the 2019 Novel Coronavirus Outbreak in China. medRxiv 2020; 2020.02.10.20021675

86 Yang X, Yu Y, Xu J, et al.: Clinical Course and Outcomes of Critically Ill Patients with SARS-CoV-2 Pneumonia in Wuhan, China: a Single-centered, Retrospective, Observational Study. Lancet Respir Med 2020; 8:475–481

87 Argenziano MG, Bruce SL, Slater CL, et al.: Characterization and Clinical Features of 1000 Patients with Coronavirus Disease 2019 in New York City: Retrospective Case Series. BMJ 2020; 369:m1996

88 Carrillo-Vega MF, Salinas-Escudero G, Garcia-Peña C, et al.: Early Estimation of the Risk Factors for Hospitalisation and Mortality by COVID-19 in Mexico. medRxiv 2020; 2020.05.11.20098145

89 Taherifard E, Taherifard E: Neurological Complications of COVID-19: a Systematic Review. Neurol Res 2020; 2020:1–8. https://doi.org/10.1080/01616412.2020.1796409. [Epub ahead of print]
induced multisystem inflammatory syndrome in children. J Clin Invest 2020;141113. https://doi.org/10.1172/JCI141113. [Epub ahead of print].

100 Dufort EM, Koumans EH, Chow EJ, et al.: Multisystem inflammatory syndrome in children in New York State. N Engl J Med 2020; 383:347–358

101 Jordan RE, Adab P, Cheng KK: Coronavirus disease-19: risk factors for severe disease and death. BMJ 2020; 368: m1198

102 Caramelo F, Ferreira N, Oliveiros B: Estimation of risk factors for COVID-19 mortality - preliminary results. medRxiv 2020; 2020.02.24.20027268

103 Deng X, Yang J, Wang W, et al.: Case fatality risk of the first pandemic wave of novel coronavirus disease 2019 (COVID-19) in China. Clin Infect Dis 2020. https://doi.org/10.1093/cid/ciaa578

104 Xie J, Tong Z, Guan X, et al.: Clinical characteristics of patients who died of coronavirus disease 2019 in China. JAMA Network Open 2020; 3: e205619

105 Choe YJ: Coronavirus disease-19: The First 7,755 cases in the republic of Korea. medRxiv 2020; 2020.03.15.20036368

106 Gupta S, Hayek SS, Wang W: Factors associated with death in critically ill patients with coronavirus disease 2019 in the US. JAMA Intern Med 2019; 2020:e203596 https://doi.org/10.1001/jamainternmed.2020.3596. [Epub ahead of print].

107 Undurraga EA, Chowell G, Mizumoto K: Case fatality risk by age from COVID-19 in a high testing setting in Latin America: Chile, March-May, 2020. medRxiv 2020. 2020.05.25.20112904

108 Bhati S, Imai N, Dorigatti I, et al.: Report 6: Relative sensitivity of international surveillance. Imperial College London, MRC Centre for Global Infectious Disease Analysis. https://www.imperial.ac.uk/mrc-globa l-infectious-disease-analysis/covid-19/report-6-international-surveillance [Last accessed 25 August 2020]

109 Weinerberger DM, Chen J, Cohen T, et al.: Estimation of excess deaths associated with the COVID-19 pandemic in the United States, March to May 2020. JAMA Intern Med 2020;2003391. https://doi.org/10.1001/jama Internmed.2020.3391

110 Giberti D, Adja KYC, Golinelli D, et al.: Patterns of COVID-19 related excess mortality in the municipalities of Northern Italy. medRxiv 2020; 2020.05.11.20097964

111 Imperial College London: MRC Centre for Global Infectious Disease Analysis. News/COVID-19. Report 4: Severity of 2019-novel coronavirus (nCoV). https://www.imperial.ac.uk/mrc-globa l-infectious-disease-analysis/covid-19/report-4-severity-of-covid-19/ [Last accessed 25 August 2020]

112 Ioannidis J: The infection fatality rate of COVID-19 inferred from seroprevalence data. medRxiv 2020; 2020.05.13.20101253

113 Sonoo M, Kanbayashi T, Shimohata T, et al.: Estimation of the true infection rate and infection fatality rate of COVID-19 in the whole population of each country. medRxiv 2020; 2020.05.13.20101071

114 Rothman J, Eidelberg D, Rothman S, et al.: Analysis of the time and age dependence of the case-fatality-ratio for COVID-19 in seven countries with a high total-to-positive test ratio suggests that the true CFR may be significantly underestimated for the United States in current models. medRxiv 2020; 2020.05.13. 20101022

115 Chen W, Lan Y, Yuan X, et al.: Detectable 2019-nCoV viral RNA in blood is a strong indicator for the illness resolution. Emerg Microbes Infect 2020; 9:469–473

116 Wang W, Xu Y, Gao R, et al.: Detection of SARS-CoV-2 in different types of clinical specimens. JAMA 2020; 323:1843–1844

117 Corman VM, Rabenau HF, Adams O, et al.: SARS-CoV-2 asymptomatic and symptomatic patients and risk for transmission transmission. Transfusion 2020; 60:1119–1122

118 Wu J, Liu J, Li S, et al.: Detection and analysis of nucleic acid in various biological samples of COVID-19 patients. Travel Med Infect Dis 2020;101673: https://doi.org/10. 1016/j.tmaid.2020.101673

119 Zheng S, Fan J, Yu F, et al.: Viral load dynamics and disease severity in patients infected with SARS-CoV-2 in Zhejiang province, China, January-March 2020: retrospective cohort study. BMJ 2020; 369:m1443

120 Kim JM, Kim HM, Lee EJ, et al.: Detection and isolation of SARS-CoV-2 in serum, urine, and stool specimens of COVID-19 patients from the Republic of Korea. Osong Public Health Res Perspect 2020; 11:112–117

121 Andersson M, Arancibia – Carcamo CV, Auckland K, et al.: SARS-CoV-2 RNA detected in blood samples from patients with COVID-19 is not associated with infectious virus. medRxiv 2020; 2020.05.21.20105486

122 Pham TD, Huang C, Wirtz OF, et al.: SARS-CoV-2 RNAemia in a healthy blood donor 40 days after respiratory illness resolution. Ann Intern Med 2020. https://doi.org/10.7326/L20-0725

123 Mostafaza A, Azize RK: Traces of SARS-CoV-2 RNA in the blood of COVID-19 patients. medRxiv 2020; 2020.05.10.20097055

124 Zaid Y, Puhm F, Allaes L, et al.: Platelets can contain SARS-CoV-2 RNA and are hyperactivated in COVID-19. medRxiv 2020; 2020.06.21.20137596

125 Zhao J, Yuan Q, Wang H, et al.: Antibody responses to SARS-CoV-2 in patients of novel coronavirus disease 2019. Clin Infect Dis 2020. https://doi.org/10.1093/cid/ciaa344

126 Long Q-X, Deng H-j, Chen J, et al.: Antibody responses to SARS-CoV-2 in COVID-19 patients: the perspective application of serological tests in clinical practice. medRxiv 2020; 2020.03.18.20038018

127 Guo L, Ren L, Yang S, et al.: Profiling early humoral response to diagnose novel coronavirus disease (COVID-19). Clin Infect Dis 2020; 71:778–785

128 Borremans B, Gamble A, Prager KC, et al.: Quantifying antibody kinetics and RNA shedding during early-phase SARS-CoV-2 infection. medRxiv 2020; 2020(05):pp. 15.20103275

129 Grzelak L, Temmam S, Planchais C, et al.: SARS-CoV-2 serological analysis of COVID-19 hospitalized
Crimean-Congo haemorrhagic fever virus and Nipah virus - in platelet concentrates by ultraviolet C light and in plasma by methylene blue plus visible light. Vox Sang 2020; 115:146–151

157 Ragan I, Hartson L, Pidcocke H, et al.: Pathogen reduction of sars-cov-2 virus in plasma and whole blood using riboflavin and UV light. bioRxiv 2020; 2020.05.03.074971

158 McCullough J, Goldfinger D, Gorlin J, et al.: Cost implications of implementation of pathogen-inactivated platelets. Transfusion 2015; 55:2312–2320

159 Mohammadi S, Tabatabaei Yazdi SM, Eshghi P: Coronavirus disease 2019 (COVID-19) and decrease in blood donation: experience of Iranian Blood Transfusion Organization (IBTO). Vox Sang 2019; 2020: https://doi.org/10.1111/vox.12930

160 Spekman MLC, van Tilburg TG, Merz EM: Do deferred donors continue their donations? A large-scale register study on whole blood donor return in the Netherlands. Transfusion 2019; 59:3657–3665

161 Davison TE, Masser BM, Gemelli CN: Deferred and deterred: a review of literature on the impact of deferrals on blood donors. ISBT Sci Ser 2020; 15:3–10

162 Sayedahmed AMS, Ali KAM, Ali SBS, et al.: Coronavirus disease (COVID-19) and decrease in blood donation: a cross-sectional study from Sudan. ISBT Sci Ser 2020. https://doi.org/10.1111/vox.12575

163 Wang Y, Han W, Pan L, et al.: Impact of COVID-19 on blood centres in Zhejiang province China. Vox Sang 2020. https://doi.org/10.1111/vox.12931

164 Grandone E, Mastroianno M, Caroli A, et al.: Blood supply and transfusion support in southern Italy: findings during the first four weeks of the SARS-CoV-2 pandemic. Blood Transfus 2020; 18:230–232

165 Leung JNS, Lee C-K: Impact of the COVID-19 – a regional blood centre’s perspective. ISBT Sci Ser 2020. https://doi.org/10.1111/vox.12558

166 US Food and Drug Administration: Revised Recommendations for Reducing the Risk of Human Immunodeficiency Virus Transmission by Blood and Blood Products. Guidance for Industry. April 2020. https://www.fda.gov/media/92490/download

[Last accessed 25 August 2020]

167 Pimenoff VN, Elstrom M, Dillner J: A systematic review of convalescent plasma treatment for COVID19. medRxiv 2020; 2020.06.05.20122830

168 Abolghasemi H, Eshghi P, Cheraghal AM, et al.: Clinical efficacy of convalescent plasma for treatment of COVID-19 infections: Results of a multicenter clinical study. Transfus Apher Sci 2020: 102875

169 Brown BL, McCullough J: Treatment for emerging viruses: Convalescent plasma and COVID-19. Transfus Apher Sci 2020; 59:102790

170 Nguyen AA, Habiballah SB, Platt CD, et al.: Immunoglobulins in the treatment of COVID-19 infection: Proceed with caution!. Clin Immunol 2020; 216:108459

171 Mansourabadi AH, Sadeghalvad M, Mohammadi-Motlagh H-R, et al.: The immune system as a target for therapy of SARS-CoV-2: A systematic review of the current immunotherapies for COVID-19. Life Sci 2020; 258:118185

Supporting Information

Additional Supporting Information may be found in the online version of this article.