

Effect of Covid-19 pandemic on sexual activity

Abstract

The aim of this study is to overview effect of Covid-19 pandemic on sexual activity where awareness of contact was prohibited to prevent virus transmission. Severity of anxiety, depression and stress were increased in this period.

Volume 11 Issue 2 - 2023

Moh'd Nizar Battikhi
1645 Demaisonnaive, Canada

Correspondence: Mohammed Nizar Battikhi, 1017-1645 De Maisonneuve O, Montreal, Quebec, H3H2N3 Canada, Tel 514-933-5613 Email m_nizal1@hotmail.ca

Received: March 25, 2023 | **Published:** April 12, 2023

Background and introduction

It is important to understand the structure and formation of Covid virus so the effect on our life style and sexual activity can be explained.¹ Coronaviruses (CoVs) belonged to the order *Nidovirales*, family *Coronaviridae* and subfamily *Coronavirinae*. They are enveloped single-stranded RNA virus with a positive sense. Genome sizes ranging from 26 to 32 kilobases (kb) in length and have the largest genomes for RNA viruses.^{1,2} Three known groups of CoVs have been reported: α -CoVs, β -CoVs, and γ -CoVs. Based on genetic and antigenic criteria.^{1,2} Novel coronavirus (SARS-CoV-2) was detected firstly in December 2019 in China (Wuhan, Hubei) then, it has rapidly spread all over the world resulted in unpredictably changes in our lives(1). Farming industry was seriously affected by CoVs due to the birds and mammals infection causing lethal disease, although CoVs infection are limited to animal as natural host (enzootic infections)^{3,4} some have crossed the animal-human species barrier and progressed to establish zoonotic diseases in humans.⁵⁻⁹ Evidence have been reported that human CoVs (HCoVs) are implicated in both upper (URTLs) like common cold and lower (URTLs) respiratory tract infections such as bronchitis, pneumonia, and even severe acute respiratory syndrome (SARS) respectively⁵⁻¹⁴ validating the importance of coronaviral research as agents of severe respiratory illnesses.^{7,9,15-17} Accordingly, these cross-species barrier jumps allowed CoVs like the SARS-CoV and Middle Eastern respiratory syndrome (MERS)-CoV to manifest as virulent human viruses. The consequent outbreak of SARS in 2003 led to pandemic with 8096 cases and 774 deaths reported worldwide, resulting in a fatality rate of 9.6% (18). Since the outbreak of MERS in April 2012 up until October 2018, 2229 laboratory-confirmed cases have been reported globally, including 791 associated deaths with a case-fatality rate of 35.5% (19). Clearly, the seriousness of these infections and the lack of effective, licensed treatments for CoV infections underpin the need for more detailed and comprehensive understanding of coronaviral molecular biology, with a specific focus on both their structural proteins as well as their accessory proteins.²⁰⁻²⁴ Live, attenuated vaccines and fusion inhibitors have proven promising, methods, but both also require an intimate knowledge of CoV molecular biology.^{23,25-30} The coronaviral genome encodes four major structural proteins: the spike (S) protein, nucleocapsid (N) protein, membrane (M) protein, and the envelope (E) protein, all of which are required to produce a structurally complete viral particle^{29,31,32} however, it has become clear that some CoVs do not require the full structural proteins to form a complete, infectious virion, suggesting that some structural proteins might be dispensable or that these CoVs might encode additional proteins with overlapping compensatory functions.^{29,31-35} Individually, each protein primarily plays a role in the structure of the virus particle, but they are

also involved in other aspects of the replication cycle. The S protein mediates attachment of the virus to the host cell surface receptors and subsequent fusion between the viral and host cell membranes facilitate viral entry into the host cell.³⁶⁻³⁸ In some CoVs, expression of S at the cell membrane can also mediate cell-cell fusion between infected and adjacent, uninfected cells. This formation of giant, multinucleated cells, or syncytia, has been proposed as a strategy to allow direct spreading of the virus between cells, subverting virus-neutralizing antibodies.³⁷⁻³⁹ Unlike the other major structural proteins, N is the only protein that functions primarily to bind to the CoV RNA genome, making up the nucleocapsid.⁴⁰ Although N is largely involved in processes relating to the viral genome, it is also involved in other aspects of the CoV replication cycle and the host cellular response to viral infection.⁴¹ Interestingly, localization of N to the endoplasmic reticulum (ER)-Golgi region has proposed a function for assembly and budding.⁴²⁻⁴⁵ However, transient expression of N was shown to substantially increase the production of virus-like particles (VLPs) in some CoVs, suggesting that it might not be required for envelope formation, but for complete virion formation instead.^{41,42,46-47} The M protein is the most abundant structural protein and defines the shape of the viral envelope.⁴⁸ It is also regarded as the central organizer of CoV assembly, interacting with all other major coronaviral structural proteins.²⁹ Homotypic interactions between M proteins are the major driving force behind virion envelope formation but, alone, is not sufficient for virion formation.⁴⁹⁻⁵⁶ Interaction of S with M is necessary for retention of S in the ER-Golgi intermediate compartment (ERGIC)/Golgi complex and its incorporation into new virions, but dispensable for the assembly process.^{37,45,57} Binding of M to N stabilizes the nucleocapsid (N protein-RNA complex), as well as the internal core of virions, and, ultimately, promotes completion of viral assembly.^{45,58,59} Together, M and E make up the viral envelope and their interaction is sufficient for the production and release of VLPs.^{37,60-64} The E protein is the smallest of the major structural proteins, but is the most enigmatic. During the replication cycle, E is abundantly expressed inside the infected cell, but only a small portion is incorporated into the virion envelope.⁶⁵ The majority of the protein is localized at the site of intracellular trafficking, viz. the ER, Golgi, and ERGIC, where it participates in CoV assembly and budding.⁶⁶ Recombinant CoVs lacking E exhibit significantly reduced viral titers, crippled viral maturation, or yield propagation incompetent progeny, demonstrating the importance of E in virus production and maturation.^{35,39,67,68} This novel coronavirus disease (COVID-19), which is transmitted by respiratory tract or by direct contact with infected surfaces, was declared as a pandemic by the World Health Organization (WHO) in March 2020 and triggered all countries to take extraordinary measures.² Almost all organizations (scientific, sportive, recreational,

etc.) have been canceled and travel has been restricted. Quarantines and curfews have become daily routines and the concept of social distancing has become our new normality, even within families, causing significant disruptions in many social relationships. Due to the fear of potential infection risk with COVID-19, time spent at home has increased and restrictions on socializing and economic losses have caused anxiety and depression in many people who have been forced to stay at home during this period.^{3,4} As it is known, quality and satisfying sexual life have a positive effect on the social and daily relationships as well as on the intimate life of many individuals.^{5,6} The WHO summarizes the definition of sexual health as the physical, emotional, mental, and social well-being of an individual.⁷ On the other hand, sexual dysfunction can be described as any condition preventing the individual from being satisfied by the sexual activity at any stage of the sexual relationship. In this manner, consistent evidence suggests that in addition to organic causes (vascular, hormonal, neurogenic, pharmacological) of sexual dysfunction, psychogenic causes, such as anxiety and depression also have a negative effect on sexual life, in both men and women.^{8,9} In a study conducted by Dunn et al, erectile dysfunction was observed 1.3–2.3-fold more in individuals with anxiety and depression (10). Similarly, Mitchell et al., reported that females with depression had 3.12-fold sexual dysfunction.¹¹ Although the mechanism of the relationship between sexual dysfunction and psychological problems is not understood yet, it is known to be reciprocal and multi-factorial¹² The addition of sexual dysfunction can worsen the already present psychopathology and create a vicious circle^{13–15} Moreover, in a study on male sexual dysfunction, it was emphasized that this vicious circle also impacted negatively on the partner and consequently on the relationship.⁹ In a study conducted in Turkey changes in the sexual lives of married or co-habiting couples in during COVID-19 pandemic period which has been on-going for a long time. Coronavirus disease 2019 (COVID-19) pandemic has been continuing to affect the lives of all people globally where Influence of COVID-19 pandemic on sexuality: a cross-sectional study among couples in Turkey was reported.⁶⁹ All people should follow control prevention precaution to stop spreading of the virus in spite of symptoms they show and regardless of whether or not they have had laboratory-confirmed Covid-19 in the past. Accumulating evidence supports ending isolation and precautions for persons with COVID-19 using a symptom-based strategy. Researchers have reported that people with mild to moderate COVID-19 remain infectious no longer than 10 days after their symptoms began, individuals with more severe illness and severely immune compromised are remain infectious no longer than 20 days after their symptoms began. Therefore, CDC has updated the recommendations for discontinuing home isolation and thus sex during pandemic requires new set of precaution considering the long lasting stay of partners together and increase incident of direct contact which obviously will enhance increase sexual activity as one way of self-pressure release under the circumstances irrespective of their psychological status of partners. COVID-19 is spread by close contact between people, including sexual contact like kissing, caresses, hugs, sexual relations, etc. This means that sexual partners must follow the health recommendations for everyone due to the fact that a person can spread COVID-19 even if they do not have any symptoms and the virus is spread from person to person by contact with respiratory droplets projected into the air by a person who is infected talks, coughs or sneezes. It can also be spread by touching contaminated surfaces with your hands and then touching your mouth, nose or eyes therefore all close contact with an infected person can expose to virus that cause corona virise disease (C0vid-2019) whether engaged in sexual activity or not. Furthermore the virus has been detected in

some body fluids such as blood, semen and stool. However, the possibility of transmission through these body fluids remains uncertain at this time. It has been reported that all close contact (within 6 feet or 2 meters) with an infected person can expose individual to the virus that causes coronavirus disease (COVID-19) — whether you're engaged in sexual activity or not. The virus spreads by respiratory droplets released by cough, sneeze or talk of symptomatic or asymptomatic person having the virus. These droplets can be inhaled or land in the mouth or nose of a person nearby. Coming into contact with a person's spit through kissing or other sexual activities could expose you to the virus. People who have COVID-19 could also spread respiratory droplets onto their skin and personal belongings. A sexual partner could get the virus by touching these surfaces and then touching his or her mouth, nose or eyes. In addition, the COVID-19 virus can spread through contact with feces. It's possible that you could get the COVID-19 virus from sexual activities that expose you to fecal matter. There is currently no evidence that the COVID-19 virus is transmitted through semen or vaginal fluids, but the virus has been detected in the semen of people who have or are recovering from the virus. Further research is needed to determine if the COVID-19 virus could be transmitted sexually. However, the Centers for Disease Control and Prevention recommend that after you are fully vaccinated you can resume your normal activities. You can also stop wearing a mask or social distancing in any setting, except where required by a rule or law. You are considered fully vaccinated 2 weeks after you get a second dose of an mRNA COVID-19 vaccine or 2 weeks after you get a single dose of the Janssen/Johnson & Johnson COVID-19 vaccine. If you haven't had a COVID-19 vaccine, it's important to continue avoiding close contact (within about 6 feet, or 2 meters) with others. This includes avoiding sexual contact with anybody who doesn't live with you. If you or your partner isn't feeling well or think you might have COVID-19, don't kiss or have sex with each other until you're both feeling better. Also, if you or your partner is at higher risk of serious illness with COVID-19 due to an existing chronic condition, you might want to avoid sex. If you haven't had a COVID-19 vaccine, the safest type of sexual activity during the COVID-19 pandemic is masturbation. Be sure to wash your hands and any sex toys used, both before and after masturbating. You might also consider engaging in sexual activity with partners via text, photos or videos, ideally using an encrypted platform to provide privacy protection. Beyond sex, there are other ways to create or maintain intimacy with a partner at a distance. Go on virtual dates together, share music you enjoy, write letters to one another or dress up for each other. Be creative.

If you are unvaccinated and sexually active with someone outside of your household, consider these precautions to reduce your risk of getting the COVID-19 virus: COVID-19 is spread by close contact between people, including sexual contact like kissing, caresses, hugs, sexual relations, etc. This means that sexual partners must follow the health recommendations for everyone. A person can spread COVID-19 even if they do not have any symptoms.

The virus is spread from person to person by contact with respiratory droplets projected into the air when a person who is infected talks, coughs or sneezes. It can also be spread by touching contaminated surfaces with your hands and then touching your mouth, nose or eyes. The virus has been detected in some body fluids such as blood, semen and stool. However, the possibility of transmission through these body fluids remains uncertain at this time.

During social distancing the question arise is how to have sex in the era of COVID-19 self-isolation and is it even safe to have sex during the pandemic?. The facts that the disease caused by the novel coronavirus, is spread by direct person-to-person contact or by people

who are close to (within six feet) of each other—as it's believed that the virus is expelled in respiratory droplets from a cough or sneeze, according to the Centers for Disease Control and Prevention (CDC), which you can then inhale or you can also pick it up from contaminated surfaces if you then touch your face without washing your hands properly first and therefore introduce the pathogen into your body.

Discussion

The effects of the global COVID-19 pandemic on the sexual lives of couples in several studies were reported. Severity of anxiety, depression, and stress perception increased in this period, an increase in sexual dysfunctions was observed^{28,29} However, other studies stated that the frequency of sexual intercourse is one of the main factors that determine the individuals' sexual satisfaction status.³⁰ Another recent study conducted by Fernandes *et al.*, where sexual satisfaction was found to be highest in the group that had sexual intercourse 4–6 times per week.³¹ Consistent with these reports, the frequency of sexual intercourse and overall sexual satisfaction levels decreased in both sexes was reported in study population in Turkey during pandemic compared to pre pandemic period ($p=0.001$)³⁰ Although an increase in the frequency of sexual intercourse (8.7% of males and (11.3%) of females was reported in Turkey due to prolong time spent together. In contrast other study conducted in Italy during COVID-19 pandemic, reduction in sexual intercourse was not recorded.³² Therefore several studies to date, reported sexual avoidance behaviors have generally been associated with different conditions, such as psychiatric diseases (major depression, obsessive compulsive disorder, etc.),^{33,34} problems between the couples (lack of intimacy, attachment problems)^{35–37} or chronic diseases (hypertension, coronary artery disease, cancer, rheumatoid arthritis, epilepsy, migraine),^{38–42} among other reasons. As the incubation period of COVID-19 can last for up to 2 weeks and individuals can be asymptomatic during that time, it may lead to concerns that the infection could be transmitted during sexual intercourse.⁴³ It has been reported that females had twofold higher sexual avoidance behaviors than males in this period ($p=0.001$). It can be explained by the fact that the perception of stress in women is significantly higher than that of men ($p=0.001$). Although it is not yet fully known whether the virus can be passed via semen or vaginal secretions in addition to the respiratory tract and direct contact,^{44–46} precautions, such as willingness to use a condom during intercourse and avoiding kissing were preferred twofold higher by females than by males ($p=0.048$). Sexual activity with a partner is known to provide a higher rate of sexual satisfaction than solitary sexual activity.⁴⁷ However, during the pandemic there was an increase in solitary sexual satisfaction approaches in both sexes, and the rate of this increase was significantly higher in males ($p=0.022$) than in female participants.^{69,70} previous studies have reported that males are more predisposed than females to start solitary or dyadic sexual activity.^{48,49}

Conclusion

Many reports showed different effects of Covid-19 virus pandemic on our life style and on sexual activities. Sexual activity with a partner is known to provide a higher rate of sexual satisfaction than solitary sexual activity. However, more studies are still need to lay out standard role for intimacy and sexuality.

Acknowledgements

None

Conflicts of interests

Authors declare no conflict of interest.

References

- Zhu N, Zhang DY, Wang WL, et al. A novel coronavirus from patients with pneumonia in China. *N Engl Med.* 2019;382(8):727–733.
- World Health Organization. *Naming the coronavirus disease (COVID-19) and the virus that causes it.* World Health Organization; 2020.
- Torales J, O'Higgins M, Castaldelli-Maia JM, et al. The outbreak of COVID-19 coronavirus and its impact on global mental health. *Int J Soc Psychiatry.* 2020;66(4):317–320.
- Özdin S, Bayrak Özdin S. Levels and predictors of anxiety, depression and health anxiety during COVID-19 pandemic in Turkish society: the importance of gender. *Int J Soc Psychiatry.* 2020;66(5):504–511.
- Van Lankveld J, Jacobs N, Thewissen V, et al. The associations of intimacy and sexuality in daily life: temporal dynamics and gender effects within romantic relationships. *J Soc Pers Relat.* 2018;35:557–576.
- Flynn KE, Lin L, Bruner DW, et al. Sexual satisfaction and the importance of sexual health to quality of life throughout the life course of US adults. *J Sex Med.* 2016;13(11):1642–1650.
- World Health Organization. *Sexual and reproductive health: defining sexual health.* WHO; 2006.
- Clayton AH, Groth J. Etiology of female sexual dysfunction. *Women's Health.* 2013;9(2):135–137.
- Hedon F. Anxiety and erectile dysfunction: a global approach to ED enhances results and quality of life. *Int J Impot Res.* 2003;15:S16–S19.
- Dunn KM, Croft PR, Hackett GI. Association of sexual problems with social, psychological, and physical problems in men and women: a cross sectional population survey. *J Epidemiol Community Health.* 1999;53(3):144–148.
- Mitchell KR, Mercer CH, Ploubidis GB, et al. Sexual function in Britain: findings from the third national survey of sexual attitudes and lifestyles (Natsal-3). *Lancet.* 2013;382(9907):1817–1829.
- Forbes MK, Baillie AJ, Schniering CA. A structural equation modeling analysis of the relationships between depression, anxiety, and sexual problems over time. *J Sex Res.* 2016;53(8):942–954.
- Michael A, O'Keane V. Sexual dysfunction in depression. *Hum Psychopharmacol Clin Exp.* 2000;15(5):337–345.
- Minnen AV, Kampman M. The interaction between anxiety and sexual functioning: a controlled study of sexual functioning in women with anxiety disorders. *Sex Relatsh Ther.* 2000;15:47–57.
- Bradford A, Meston CM. The impact of anxiety on sexual arousal in women. *Behav Res Ther.* 2006;44(8):1067–1077.
- Spitzer RL, Kroenke K, Williams JB, et al. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med.* 2006;166(10):1092–1097.
- Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med.* 2001;16(9):606–613.
- Hon CC, Lam TY, Shi ZL, et al. Evidence of the recombinant origin of a bat severe acute respiratory syndrome (SARS)-like coronavirus and its implications on the direct ancestor of SARS coronavirus. *J Virol.* 2008;82(4):1819–1826.
- World Health Organization (WHO). *Summary of probable SARS cases with onset of illness from 1 November 2002 to 31 July 2003;* 2015.
- Lou Z, Sun Y, Rao Z. Current progress in antiviral strategies. *Trends Pharmacol Sci.* 2014;35(2):86–102.
- Kilianski A, Baker SC. Cell-based antiviral screening against coronaviruses: Developing virus-specific and broad-spectrum inhibitors. *Antivir Res.* 2014;101:105–112.

22. Kilianski A, Mielech A, Deng X, et al. Assessing activity and inhibition of MERS-CoV papain-like and 3C-like proteases using luciferase-based biosensors. *J Virol.* 2013;87(21):11955–11962.
23. Masters PS. The molecular biology of coronaviruses. *Adv Virus Res.* 2006;66:193–292.
24. Liu DX, Fung TS, Chong KKL, et al. Accessory proteins of SARS-CoV and other coronaviruses. *Antivir Res.* 2014;109:97–109.
25. Heald-Sargent T, Gallagher T. Ready, set, fuse! The coronavirus spike protein and acquisition of fusion competence. *Viruses.* 2012;4(4):557–580.
26. Graham RL, Becker MM, Eckerle LD, et al. A live, impaired-fidelity coronavirus vaccine protects in an aged, immune compromised mouse model of lethal disease. *Nat Med.* 2012;18(12):1820–1826.
27. Enjuanes L, Nieto-Torres JL, Jimenez-Guardeño JM, et al. *Recombinant live vaccines to protect against the severe acute respiratory syndrome coronavirus.* In: Dormitzer P, Mandl CW, Rappuoli R, editors. *Replicating vaccines, Birkhauser advances in infectious diseases book series (BAID).* Basel: Springer. 2011;73–97p.
28. Regla-Nava JA, Nieto-Torres JL, Jimenez-Guardeño JM, et al. SARS coronaviruses with mutations in E protein are attenuated and promising vaccine candidates. *J Virol.* 2015;89(7):3870–3887.
29. DeDiego ML, Álvarez E, Almazán F, et al. A severe acute respiratory syndrome coronavirus that lacks the E gene is attenuated in vitro and in vivo. *J Virol.* 2007;81(4):1701–1713.
30. Netland J, DeDiego ML, Zhao J, et al. Immunization with an attenuated severe acute respiratory syndrome coronavirus deleted in E protein protects against lethal respiratory disease. *Virology.* 2010;399(1):120–128.
31. Mortola E, Roy P. Efficient assembly and release of SARS coronavirus-like particles by a heterologous expression system. *FEBS Lett.* 2004;576(1–2):174–178.
32. Carmack Taylor CL, Basen-Engquist K, Shinn EH. Predictors of sexual functioning in ovarian cancer patients. *J Clin Oncol.* 2004;22(5):881–889.
33. Rathore C, Henning OJ, Luef G, et al. Sexual dysfunction in people with epilepsy. *Epilepsy Behav.* 2019;100:106495.
34. Kucukdurmaz F, Inanc Y, Resim S. Sexual dysfunction and distress in premenopausal women with migraine: association with depression, anxiety and migraine-related disability. *Int J Impot Res.* 2018;30(5):265–271.
35. Zhou R, Li F, Chen F, et al. Viral dynamics in asymptomatic patients with COVID-19. *Int J Infect Dis.* 2020;96:288–290.
36. de Haan CA, Rottier PJ. Molecular interactions in the assembly of coronaviruses. *Adv Virus Res.* 2005;64:165–230.
37. McBride R, van Zyl M, Fielding BC. The coronavirus nucleocapsid is a multifunctional protein. *Viruses.* 2014;6(8):2991–3018.
38. Qian Z, Dominguez SR, Holmes KV. Role of the spike glycoprotein of human middle East respiratory syndrome coronavirus (MERS-CoV) in virus entry and syncytia formation. *PLoS One.* 2013;8(10):e76469.
39. Pan F, Xiao X, Guo J, et al. No evidence of severe acute respiratory syndrome-coronavirus 2 in semen of males recovering from coronavirus disease 2019. *Fertil Steril.* 2020;113(6):1135–1139.
40. Beck JG, Bozman AW, Qualtrough T. The experience of sexual desire: psychological correlates in a college sample. *J Sex Res.* 1991;28(3):443–456.
41. Tooze J, Tooze S, Warren G. Replication of coronavirus MHV-A59 in sac-cells: Determination of the first site of budding of progeny virions. *Eur J Cell Biol.* 1984;33(2):281–293.
42. Klumperman J, Locker JK, Meijer A, et al. Coronavirus M proteins accumulate in the Golgi complex beyond the site of virion budding. *J Virol.* 1994;68(10):6523–6534.
43. Boscarino JA, Logan HL, Lacny JJ, et al. Envelope protein palmitoylations are crucial for murine coronavirus assembly. *J Virol.* 2008;82(6):2989–2999.
44. Ruch TR, Machamer CE. The hydrophobic domain of infectious bronchitis virus E protein alters the host secretory pathway and is important for release of infectious virus. *J Virol.* 2011;85(2):675–685.
45. Neuman BW, Kiss G, Kunding AH, et al. A structural analysis of M protein in coronavirus assembly and morphology. *J Struct Biol.* 2011;174(1):11–22.
46. de Haan CA, Vennema H, Rottier PJ. Assembly of the coronavirus envelope: homotypic interactions between the M proteins. *J Virol.* 2000;74(11):4967–4978.
47. Lim K, Liu D. The missing link in coronavirus assembly: retention of the avian coronavirus infectious bronchitis virus envelope protein in the pre-Golgi compartments and physical interaction between the envelope and membrane proteins. *J Biol Chem.* 2001;276(20):17515–17523.
48. Opstelten DJ, Raamsman M, Wolfs K, et al. Envelope glycoprotein interactions in coronavirus assembly. *J Cell Biol.* 1995;131(2):339–349.
49. Escors D, Ortega J, Laude H, et al. The membrane M protein carboxy terminus binds to transmissible gastroenteritis coronavirus core and contributes to core stability. *J Virol.* 2001;75(3):1312–1324.
50. Narayanan K, Maeda A, Maeda J, et al. Characterization of the coronavirus M protein and nucleocapsid interaction in infected cells. *J Virol.* 2000;74(17):8127–8134.
51. Corse E, Machamer CE. Infectious bronchitis virus E protein is targeted to the Golgi complex and directs release of virus-like particles. *J Virol.* 2000;74(9):4319–4326.
52. Corse E, Machamer CE. The cytoplasmic tails of infectious bronchitis virus E and M proteins mediate their interaction. *Virology.* 2003;312(1):25–34.
53. Bos EC, Luytjes W, van der Meulen H, et al. The production of recombinant infectious DI-particles of a murine coronavirus in the absence of helper virus. *Virology.* 1996;218(1):52–60.
54. Vennema H, Godeke GJ, Rossen J, et al. Nucleocapsid-independent assembly of coronavirus-like particles by co-expression of viral envelope protein genes. *EMBO J.* 1996;15(8):2020–2028.
55. Baudoux P, Carrat C, Besnardau L, et al. Coronavirus pseudoparticles formed with recombinant M and E proteins induce alpha interferon synthesis by leukocytes. *J Virol.* 1998;72(11):8636–8643.
56. Venkatagopalan P, Daskalova SM, Lopez LA, et al. Coronavirus envelope (E) protein remains at the site of assembly. *Virology.* 2015;478:75–85.
57. Nieto-Torres JL, DeDiego ML, Álvarez E, et al. Subcellular location and topology of severe acute respiratory syndrome coronavirus envelope protein. *Virology.* 2011;415(2):69–82.
58. Curtis KM, Yount B, Baric RS. Heterologous gene expression from transmissible gastroenteritis virus replicon particles. *J Virol.* 2002;76(3):1422–1434.
59. Ortega J, Escors D, Laude H, et al. Generation of a replication-competent, propagation-deficient virus vector based on the transmissible gastroenteritis coronavirus genome. *J Virol.* 2002;76(22):11518–11529.
60. Kuo L, Hurst KR, Masters PS. Exceptional flexibility in the sequence requirements for coronavirus small envelope protein function. *J Virol.* 2007;81(5):2249–2262.
61. Arbely E, Khattari Z, Brotons G, et al. A highly unusual palindromic transmembrane helical hairpin formed by SARS coronavirus E protein. *J Mol Biol.* 2004;341(3):769–779.

62. Raamsman MJ, Locker JK, de Hooge A, et al. Characterization of the coronavirus mouse hepatitis virus strain A59 small membrane protein E. *J Virol*. 2000;74(5):2333–2342.
63. Li Y, Surya W, Claudine S, et al. Structure of a conserved Golgi complex-targeting signal in coronavirus envelope proteins. *J Biol Chem*. 2014;289(18):12535–12549.
64. Liao Y, Yuan Q, Torres J, et al. Biochemical and functional characterization of the membrane association and membrane permeabilizing activity of the severe acute respiratory syndrome coronavirus envelope protein. *Virology*. 2006;349(2):264–275.
65. Surya W, Samsó M, Torres J. *Structural and functional aspects of viroporins in human respiratory viruses: respiratory syncytial virus and coronaviruses*. Respiratory Disease and Infection - A New Insight. InTech; 2013.
66. Torres J, Maheswari U, Parthasarathy K, et al. Conductance and amantadine binding of a pore formed by a lysine-flanked transmembrane domain of SARS coronavirus envelope protein. *Protein Sci*. 2007;16(9):2065–2071.
67. Verdiá-Báguena C, Nieto-Torres JL, Alcaraz A, et al. Coronavirus E protein forms ion channels with functionally and structurally-involved membrane lipids. *Virology*. 2012;432(2):485–494.
68. Nieto-Torres JL, DeDiego ML, Verdiá-Báguena C, et al. Severe acute respiratory syndrome coronavirus envelope protein ion channel activity promotes virus fitness and pathogenesis. *PLoS Pathog*. 2014;10(5):e1004077.
69. Scholar Impett EA, Peplau LA, Gable SL. Approach and avoidance sexual motives: Implications for personal and interpersonal well-being. *Personal Relatsh*. 2005;12:465–482.
70. Ali Karagöz M, Gül A, Borg C, et al. Influence of COVID-19 pandemic on sexuality: a cross-sectional study among couples in Turkey. *International Journal of Impotenc*; 2020;33:815–823.