One year into the COVID-19 pandemic: What do we know so far from studies assessing risk and mitigation of droplet aerosolisation during endonasal surgery? A systematic review

Stephen Williams[1] and Samuel Leong[1]

[1]Liverpool University Hospitals NHS Foundation Trust

May 9, 2021

Abstract

Objectives As we pass the anniversary of the declaration of a global pandemic by the World Health Organisation, it invites us to reflect upon the inescapable changes that coronavirus has wrought upon ENT and, in particular, rhinological practice. As it remains unclear when we will globally emerge from the shadow of COVID-19, a critical analysis of the evidence base on both the assessment and mitigation of risk is vital for ENT departments worldwide. This article presents a systematic review of the literature examining articles which consider either the quantification of risk or strategies to mitigate risk specifically in the setting of rhinological surgery. Design Systematic literature review. Results The literature search yielded a total of 3406 returns with 24 articles meeting eligibility criteria. A narrative synthesis stratified results into two broad themes: those which made an assessment as to the aerosolisation of droplets during sinus surgery, further subdivided into work which considered macroscopically visible droplets and that which considered smaller particles, and those studies which examined the mitigation of this risk. Conclusion Studies considering the aerosolisation of both droplets and smaller particles suggest endonasal surgery carries significant risk. Whilst results both highlight a range of innovative adjunctive strategies and support suction as an important variable to reduce aerosolisation, appropriate use of personal protective equipment (PPE) should be considered mandatory for all healthcare professionals involved in rhinological surgery given studies have demonstrated that close adherence to PPE use is effective at preventing COVID-19 infection.

One year into the COVID-19 pandemic: What do we know so far from studies assessing risk and mitigation of droplet aerosolisation during endonasal surgery? A systematic review

Abstract

Objectives

As we pass the anniversary of the declaration of a global pandemic by the World Health Organisation, it invites us to reflect upon the inescapable changes that coronavirus has wrought upon ENT and, in particular, rhinological practice. As it remains unclear when we will globally emerge from the shadow of COVID-19, a critical analysis of the evidence base on both the assessment and mitigation of risk is vital for ENT departments worldwide. This article presents a systematic review of the literature examining articles which consider either the quantification of risk or strategies to mitigate risk specifically in the setting of rhinological surgery.

Design

Systematic literature review.

Results

The literature search yielded a total of 3406 returns with 24 articles meeting eligibility criteria. A narrative synthesis stratified results into two broad themes: those which made an assessment as to the aerosolisation of droplets during sinus surgery, further subdivided into work which considered macroscopically visible droplets and that which considered smaller particles, and those studies which examined the mitigation of this risk.

Conclusion

Studies considering the aerosolisation of both droplets and smaller particles suggest endonasal surgery carries significant risk. Whilst results both highlight a range of innovative adjunctive strategies and support suction as an important variable to reduce aerosolisation, appropriate use of personal protective equipment (PPE) should be considered mandatory for all healthcare professionals involved in rhinological surgery given studies have demonstrated that close adherence to PPE use is effective at preventing COVID-19 infection.

Key points

- Endonasal surgery performed using either cold steel or powered instrumentation is an aerosol generating procedure, with both macroscopically visible droplets and particles smaller than 10µm detected outside the nasal cavity during simulated surgery.
- The results of several case series suggest that combining preoperative patient screening and PPE use is successful in mitigating risk of infection.
- Suction, and in particular the introduction of additional suction devices, has been demonstrated to reduce aerosolisation during simulated rhinological surgery.
- Though a number of innovative adjunctive strategies have been proposed for mitigating risk, there is limited data to support their widespread adoption over other methods.
- No study has considered the presence of viability of COVID-19 within droplets aerosolised from the nasal cavity which represents a notable limitation on work to date.

Introduction

March 2020 marked both the first national lockdown in the United Kingdom and the declaration of a global pandemic by the World Health Organisation. As we pass the unhappy anniversary of this time, it invites us to reflect upon the inescapable changes that coronavirus has wrought upon ENT practice. A series of measures were put in place to prevent health services being overwhelmed by COVID-19, initially involving the cancellation of elective surgery across the country. Whilst this primarily aimed to allow reallocation of resources, specific concerns were also raised about the safety of healthcare professionals during surgical procedures.[1] Coronaviruses are around 0.125µm in size but are frequently carried in larger respiratory droplets.[2] Transmission is primarily through spread of these droplets and this places those specialties with frequent exposure to oronasal secretions at particularly high risk. Logical reasoning suggests that instrumentation of the nasal cavity has the potential to aerosol these droplets and small particles and so risk spread of coronavirus infection during rhinological surgery.

In order that important clinical practice can continue, the last twelve months have seen a host of institutions attempt to both quantify the risk rhinological surgery presents and mitigate it, often through implementing creative innovations. COVID-19 is truly a global pandemic and ENT departments worldwide are all the in same position of needing to continue with emergent and, where possible, elective work in a safe manner. This article presents a systematic review of the literature examining articles considering either the quantification of risk or strategies to mitigate risk in the setting of rhinological surgery.

Methods

Ethical considerations

This was a systematic literature review. No patients or volunteers were involved and therefore formal ethics committee approval was not sought.

Search strategy

This review was performed in keeping with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidance.[3] Under institutional licensing agreement, the Ovid (Wolters Kluwer N.V.) portal was used to search the MEDLINE database (U.S. National Library of Medicine) between 1 December 2020 and 4 March 2021. Search terms used were "covid-19" OR "SARS-CoV-2" AND "sinus surgery" OR "endonasal" OR "transnasal" OR "rhinology" OR "skull base" OR "nasal surgery". Results were restricted to those in the English language.

All studies relating to either the assessment or mitigation of aerosolisation risk, in the setting of rhinological surgery in COVID-19 were included. It was stipulated studies either provide some form of empirical data or propose a specific novel intervention. Both clinical and simulation studies were included. Opinion and editorial pieces were excluded.

In this review, the term “aerosol” is used to refer to both droplets and smaller airborne particles (<10µm), though they are referenced separately where possible.

Database searches were performed and screened by both authors with discrepancies resolved through discussion. Reference lists of included papers were scrutinised for further studies. The heterogeneous nature of the studies included precluded meta-analysis and so a qualitative synthesis was chosen to present the results. Where possible, risk of bias assessment was performed using ROBINS-I (Risk of Bias In Nonrandomised Studies) criteria.[4] Studies were also graded as to their level of evidence using the Oxford Centre for Evidence-Based Medicine criteria.[5]

Results

The literature search yielded 3406 returns. The PRISMA flow chart can be found in *Figure 1* . With duplicates removed, 3305 were screened based on both titles and abstracts. In keeping with the above criteria, 3275 articles were excluded based on lack of relevance. Twenty-nine full-text articles were scrutinised for eligibility. Six were excluded: two review articles[6,7] and four editorial/opinion pieces.[8-11] One further study was identified from analysis of reference lists,[12] resulting in a total of 24 articles meeting eligibility criteria.

Given the heterogeneity of the studies (*Table 1*), results were stratified into two broad themes: 1. aerosolisation of droplets during endonasal surgery, further subdivided into those which consider macroscopically visible droplets (1.1) and those which consider smaller particles (1.2), and 2. mitigation of risk.

1. Aerosolisation of droplet during sinus surgery

1.1 Macroscopically visible droplets

Macroscopically visible droplet spread was assessed in six studies, all of which used florescent tracers to map droplet spread[13-18]. All of these studies demonstrated that use of a high-speed drill aerosolised droplets outside of the nasal cavity.[13-18] No detectable droplet spread was detected in two studies considering use of non-powered “cold” instrumentation,[13,14] and one assessing utilisation of an ultrasonic aspirator (UST-2001; Stryker Co., USA).[14]

Both Sharma et al. (2020)[14] and Leong et al. (2021)[15] found that microdebrider use on cadaveric nasal mucosa had the propensity to generate extranasal droplets seen on examination under UV light. Contradictory results were found by other groups though with Workman et al. (2020a)[13] and Jones et al. (2020)[16], working in similar cadaveric settings, noting that microdebrider application to nasal mucosa did not produce detectable droplets.

1.2 Smaller particles

The aerosolisation of smaller particles ([?]10µm) was considered by six studies[19-24]. An optical particle counter (OPC) was used by the majority,[19-23] permitting detection of such particles and assessing their number, concentration, and size. Using an OPC capable of detecting particles 1.0-10.0µm (OPS 3330; TSI Inc., USA), Workman et al. (2020b)[19] analysed aerosolisation following cold steel instrumentation, electrocautery and use of the microdebrider and high-speed drill in a cadaveric setting. Readings were taken with 30 second periods of activity. Significant particles were detected following electrocautery and high-speed drill application to the sphenoid rostrum but no particles were detected with either cold steel instrumentation or microdebrider use. A further study from the same group also detected particles <10µm in size following endonasal high-speed drill use.[20]

Later work by Sharma et al. (2021a)[21] also utilised an OPC but considered even smaller particles, ranging 0.3-10µm (OPS 3330; TSI Inc., USA). In a similar cadaveric study to that of Workman et al. (2020b)[19] above, they performed cold steel instrumentation, electrocautery and tested use of the microdebrider, high-speed drill and ultrasonic aspirator. In contrast, they found that all procedures produced significant increases in particles <10µm compared to baseline, noting that most particles were <1µm, explaining the disparity between their work and that of Workman et al. (2020b). Sharma et al. (2021a)[21] also showed significant differences in particle detection between procedures, with the use of the high-speed drill generating the most and powered endoscopic sinus surgery simulations the least. That the use of the microdebrider during these simulations generated lower levels of aerosols than cold instrumentation could also be linked to the role of suction within the microdebrider device.

Although OPC technology allows quantification of particles <10µm, it does not consider their aerodynamic properties. The use of a cascade impactor allows for not only particle detection but also an assessment as to their momentum, based on density and speed. Such results are arguably more useful in measuring risk of aerosolisation than those captured by OPC alone and, based on this, Dharmarajan et al. (2020)[24] performed cadaveric simulations with cascade impactor (Next Generation Impactor; Copley Scientific, UK) and fluorescent tracer. In keeping with similar work, they demonstrated production of particles <3.30µm after endonasal drilling but, using riboflavin as a tracer, were able to filter results to confirm that particles detected were fluorescent and so from the drilled surface.

Moving from simulation studies to those with patients, Murr et al. (2020)[22] analysed particle detection during five endonasal procedures taking serial OPC readings at the position of the surgeon, scrub practitioner and anaesthetist. Significant increases in particles 0.3-10µm were measured with microdebrider and drill use but not for cold instrumentation. Sharma et al. (2021b)[23]analysed nine endonasal surgeries and mapped to a log of intraoperative steps, with specific attention to use of the microdebrider, drill and coblator. Results showed spikes in particles between 0.3-10µm during sinus surgery (including during cold instrumentation) and skull base surgery (during electrocautery and coblation). Results failed to show detectable spikes during high-speed drill use, contrasting with all other studies considering this activity. The reasons for this remain unclear but could reflect limitations in sample size, given such clinical work to date has been small in scale and experimental studies, though more numerous, also remain limited in the number of simulations performed.

2. Mitigation of risk

Nineteen studies considered techniques to mitigate this risk and they will be considered in terms of those which employ "standard" precautions, those which investigate the role of suction on aerosolisation and those which report novel adjunctive techniques.[12,14-16,18,20,21,24-35]

2.1 Standard precautions

Four studies report their experience of endonasal surgery during COVID-19 with cumulative patient number of 305.[12,25-27] Risk is mitigated through a combination of pre-operative patient testing (with or without detail of subsequent self-isolation for patients) and staff PPE use in the operating theatre, with no added precautions unique to endonasal surgery. Though there were subtle differences between each, all can be considered to reflect variation in standard operating procedure between institutions. None make specific measurements as to aerosolisation but patient and/or staff infection levels are reported as an outcome of risk mitigation. Naik et al. (2020)[25] and the work from the CRANIAL Consortium (2021)[26] report no symptomatic COVID-19 infections in patients at 14 and 30 days postoperatively, though no formal testing was performed. Penner et al. (2020)[12] and Taha et al. (2020)[27] tested staff and found no evidence of COVID-19 infection during their case series. Taken as a whole, results suggest that preoperative patient screening, to ensure patients are COVID-19-negative, and PPE use is successful in mitigating risk, though limitations apparent in these case series include lack of description as to local level of endemic infection and so relative risk at each institution, consistency in testing of patients and staff across studies and possible unreported asymptomatic infections.

2.2 Role of suction

The potential mitigation effects of suction during endonasal surgery were evaluated in five studies.[14,15,20,21,24] Two studies considered the role of suction in mitigating spread of droplets. Sharma et al. (2020)[14] noted that the introduction of a third hand for concurrent suction completely eliminated detection of fluorescein-soaked droplets following use of both microdebrider and endonasal drill. Leong et al. (2021)[15] also noted that suction during microdebrider use eliminated droplet spread, achieved through use of the inbuilt suction alone (without an additional device) provided microdebrider hand-piece settings were set at 2000rpm oscillation, 25mL/min irrigation and 200mmHg suction pressure. The results of Leong et al. (2021)[15] differed from those of Sharma et al. (2020)[14] in their finding of ongoing droplet spread despite the addition of a second suction device during high-speed drill use. This could be explained by methodological differences however as though the drilling simulations in the Sharma et al. (2020) study were run for a longer duration than those by Leong et al. (2021) (being three minutes rather than one minute of powered instrumentation), the concentration of fluorescent tracer used in their cadaveric work was much lower (1mg/mL of fluorescein versus 40mg/mL).

Workman et al. (2020c)[20], Dharmarajan et al. (2021)[24] and Sharma et al. (2021a)[21]examined the role of suction in mitigating the spread of smaller particles [?]10µm in size. Workman et al. (2020c)[20]noted a reduction in the detection of particles 1-10µm down to baseline levels, with use of a third-hand delivering nasopharyngeal suction, during simulated high-speed drilling of both the sphenoid rostrum and medial maxillary wall for five-minute periods. Dharmarajan et al. (2021)[24] also found that in two-minute simulations of drilling of the sphenoid rostrum, detection of particles [?]3.3µm were eliminated through use of an additional third-hand suction device, irrespective of whether it was positioned within the nasopharynx or just inside the nasal cavity. As has been discussed above, the work of Sharma et al. (2021a)[21] considered a greater range of particles 0.3-10µm. They also noted the significant impact of adding in concurrent rigid suction with marked reduction in particle detection following simulations of sphenoid drilling, electrocautery and use of the ultrasonic aspirator but, perhaps in keeping with the greater sensitivity of the OPC they utilised, their study did reveal that aerosolisation was ongoing despite the reductions described. Sharma et al. (2021a)[21] delved further into the impact of suction, comparing the impact of concurrent endonasal suction with both the construction of a suction ring surrounding the nares and a surgical smoke evacuation system, mounted over the patient's mouth. They noted the surgical smoke evacuation system to be the most superior device, recommending its use alongside concurrent nasal rigid suction to mitigate risk further.

2.3 Adjunctive techniques

Other groups have considered more novel applications to mitigate risk. Three studies tested the fitment of a specific mask on the patient.[16,18,28] All such work was performed in simulated settings and considered droplet spread in terms of splatter evaluated through fluorescent tracing with fluorescein. Viera-Artiles et al. (2020)[28] and Helman et al. (2020)[18] used 3-D printed mask designs and evaluated droplet dispersal following endonasal high-speed drill use. Whilst both studies noted a reduction in droplet detection, neither prevented droplet aerosolisation completely. Jones et al. (2020)[16] added suction beneath their patient mask to create a negative pressure environment finding that droplet spread was eliminated during cadaveric sinus surgery simulations using both the microdebrider and high-speed drill. Though encouraging, this work does not consider aerosolisation of smaller particles.

Five very similar feasibility studies report on their experience of specific patient draping.[29-33] The majority employ a polythene sheet, under which the surgeon operates.[29-32] Of these, only Arefin et al. (2021)[29]

published outcomes, reporting no COVID-19 infections amongst twelve theatre team members over a five-month period. Both Ioannidis et al. (2020)[34] and David et al. (2020)[35] also draped the patient in a polythlene sheet but, in a similar strategy to Jones et al. (2020)[16]above, attached suction to create a negative pressure environment. Ioannidis et al. (2020)[34] considered the aerosolisation of small particles, simulated with a smoke generator in a plastic manikin. An OPC (Fluke 985; Fluke Co., USA) was used to measure particles 0.3-0.5µm which were still detected outside of their drape system, albeit at reduced levels. Similarly, David et al. (2020)[35] found that fluorescein droplets continued to be noted outside of their draping in two of four patients evaluated.

Discussion

Synopsis of key/new findings

Studies considering the aerosolisation of both droplets and smaller particles suggest endonasal surgery carries significant risk.[13-24] Endonasal surgery performed using either cold steel or powered instrumentation has the propensity to be aerosol generating with both macroscopically visible droplets and particles <10µm detected outside the nasal cavity during simulated surgery.[13-24]

Clinical applicability of this review

Regardless of vaccination status and testing, appropriate PPE use should remain mandatory for all healthcare professionals involved in endonasal rhinological and skull base surgery. Indeed, studies have demonstrated that close adherence to PPE use, particularly with use of FFP3 level masks, is effective at preventing COVID-19 infection.[12,25-27]

Results propose suction as an important variable to reduce aerosolisation.[14,15,20,21,24] Accordingly, surgeons should consider introducing a second suction device via a three-hand technique. When using devices with in-built suction capabilities, surgeons must be aware of techniques to unblock instruments safely and to prevent blockage (e.g. adequate irrigation, reducing oscillations to allow suction to work). Furthermore, there is evidence to suggest that a greater understanding of both the design and functionality of instruments used during rhinological surgery can also be beneficial to not only optimize operational capability but also reduce aerosolisation of fluid from the surgical field.

The addition of a variety of adjunctive techniques (e.g. drapes,[29-35] negative-pressure masks[16.18,28]) reflect the ingenuity of clinical groups across the world. Though innovative, such ideas would benefit from extended real-life testing and should also be balanced with their practicality and cost given that results suggest they do not eliminate aerosolisation to the point where staff would not wear higher levels of PPE.

Areas for future research

Whilst there is an obvious need for larger scale clinical studies to attempt to support some of the more tentative findings reviewed here, there are some specific avenues in which future work could be focused. Although OPC technology has allowed studies to test for particles as small as 0.3µm, some reports place COVID-19 at 0.1µm in diameter.[2] Ideally work should employ methods of detecting particles of this size to prevent underestimation when assessing risk.

Ultimately, whilst there are a host of studies considering the spread of both droplets,[13-18] through which COVID-19 has been reported to spread, and smaller particles,[19-24] of which COVID-19 is one, all work has been somewhat indirect in its methodology with no studies able to ascertain whether COVID-19 would be found in any of the aerosols detected or, and somewhat crucially, whether it would be viable to cause infection in another host. Whilst it is challenging to prescribe the best means by which to achieve these aims, harnessing existing methods for sampling airborne viruses may provide more definitive answers.[36]

Limitations of this review

As with all systematic reviews, the search strategy employed was broad and it is expected that some studies may have been missed. The search strategy was also limited to those published in English. Readers should exercise caution that the studies reviewed here represent a single point of time and the findings of future work could alter the conclusions drawn here.

Finally, it could be posited that studies considering either the assessment of aerosolisation or mitigation of risk in literature from other specialties (e.g. Anaesthetics) or from other research sectors (e.g. Engineering) could be transferable to rhinological practice. Whilst it could be logically reasoned that findings from such work may be extrapolated to rhinology surgery, this would have involved a series of assumptions and would significantly limit the strength of any conclusions which could be drawn when results are applied in a different and untested context.

Conclusion

Though largely confined to simulated settings, the current body of evidence suggests that routine rhinological practice has the capacity to create significant aerosolisation of both droplets and smaller particles.[13-24] Whilst several studies suggest this can be mitigated to a degree, primarily through use of suction,[14,15,20,21,24] it is challenging to recommend specific mitigation strategies that will eliminate risk completely, particularly with use of the high-speed drill. Studies do indicate that close adherence to standard operating procedures,[12,25-27] concerning both pre-operative patient testing and intraoperative PPE use for staff, can be effective at preventing spread of COVID-19 during rhinological surgery.

References

1. Tysome JR, Bhutta MF. COVID-19: Protecting our ENT Workforce. Clin Otolaryngol. 2020 May;45(3):311-312.
2. Bar-On YM, Flamholz A, Phillips R, Milo R. SARS-CoV-2 (COVID-19) by the numbers. Elife. 2020;9:e57309.
3. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg. 2010;8:336–341.
4. Sterne JAC, Hernán MA, McAleenan A, Reeves BC, Higgins JPT. Chapter 25: Assessing risk of bias in a non-randomized study. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). Cochrane Handbook for Systematic Reviews of Interventions version 6.2 (updated February 2021). Cochrane, 2021
5. OCEBM (Oxford Centre for Evidence-Based Medicine) Levels of Evidence https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebm-levels-of-evidence [Last accessed 22/04/21]
6. Spock T, Kessler R, Lerner D, Filip P, Del Signore A, Colley P, Morgenstern P, Schaberg M, Bederson J, Govindaraj S, Iloreta AM, Shrivastava R. Endoscopic Skull Base Surgery Protocol From the Frontlines: Transnasal Surgery During the COVID-19 Pandemic. Otolaryngol Head Neck Surg. 2020 Sep;163(3):482-490.
7. Howard BE, Lal D. Rhinologic Practice Special Considerations During COVID-19: Visit Planning, Personal Protective Equipment, Testing, and Environmental Controls. Otolaryngol Head Neck Surg. 2020 Oct;163(4):676-681.
8. Van Gerven L, Hellings PW, Cox T, Fokkens W, Hopkins C, Hox V, Jorissen M, Schuermans A, Sinonquel P, Speleman K, Vander Poorten V, Van Gool K, Van Zele T, Alobid I. Personal protection and delivery of rhinologic and endoscopic skull base procedures during the COVID-19 outbreak. Rhinology. 2020 Jun 1;58(3):289-294.
9. Setzen M, Svider PF, Pollock K. COVID-19 and rhinology: A look at the future. Am J Otolaryngol. 2020 May-Jun;41(3):102491.
10. Patel ZM, Fernandez-Miranda J, Hwang PH, Nayak JV, Dodd R, Sajjadi H, Jackler RK. Precautions for Endoscopic Transnasal Skull Base Surgery During the COVID-19 Pandemic. Neurosurgery. 2020 Jul 1;87(1):E66-E67.
11. Radulesco T, Verillaud B, Béquignon E, Papon JF, Jankowski R, Le Taillandier De Gabory L, Dessi

P, Coste A, Serrano E, Vergez S, Simon F, Couloigner V, Rumeau C, Michel J; French Association of Rhinology (AFR); French Society of Otorhinolaryngology, Head and Neck Surgery (SFORL). COVID-19 and rhinology, from the consultation room to the operating theatre. Eur Ann Otorhinolaryngol Head Neck Dis. 2020 Sep;137(4):309-314.

12. Penner F, Grottoli S, Lanotte MMR, Garbossa D, Zenga F. Pituitary surgery during Covid-19: a first hand experience and evaluation. J Endocrinol Invest. 2021 Mar;44(3):635-636.
13. Workman AD, Welling DB, Carter BS, Curry WT, Holbrook EH, Gray ST, Scangas GA, Bleier BS. Endonasal instrumentation and aerosolization risk in the era of COVID-19: simulation, literature review, and proposed mitigation strategies. Int Forum Allergy Rhinol. 2020 Jul;10(7):798-805.
14. Sharma D, Rubel KE, Ye MJ, Shipchandler TZ, Wu AW, Higgins TS, Burgin SJ, Ting JY, Illing EA. Cadaveric Simulation of Endoscopic Endonasal Procedures: Analysis of Droplet Splatter Patterns During the COVID-19 Pandemic. Otolaryngol Head Neck Surg. 2020 Jul;163(1):145-150.
15. Leong SC, Mogre D, Andrews P, Davies E. Reducing the risks of endoscopic sino-nasal surgery in the Covid-19 era. Clin Otolaryngol. 2021 Feb 16.
16. Jones HAS, Salib RJ, Harries PG. Reducing Aerosolized Particles and Droplet Spread in Endoscopic Sinus Surgery during COVID-19. Laryngoscope. 2020 Aug 15:10.1002/lary.29065.
17. Sim ES, Dharmarajan H, Boorgu DSSK, Goyal L, Weinstock M, Whelan R, Freiser ME, Corcoran TE, Jabbour N, Wang E, Chi DH. Novel Use of Vitamin B2 as a Fluorescent Tracer in Aerosol and Droplet Contamination Models in Otolaryngology. Ann Otol Rhinol Laryngol. 2021 Mar;130(3):280-285.
18. Helman SN, Soriano RM, Tomov ML, Serpooshan V, Levy JM, Pradilla G, Solares CA. Ventilated Upper Airway Endoscopic Endonasal Procedure Mask: Surgical Safety in the COVID-19 Era. Oper Neurosurg (Hagerstown). 2020 Sep 1;19(3):271-280.
19. Workman AD, Jafari A, Welling DB, Varvares MA, Gray ST, Holbrook EH, Scangas GA, Xiao R, Carter BS, Curry WT, Bleier BS. Airborne Aerosol Generation During Endonasal Procedures in the Era of COVID-19: Risks and Recommendations. Otolaryngol Head Neck Surg. 2020 Sep;163(3):465-470.
20. Workman AD, Xiao R, Feng A, Gadkaree SK, Quesnel AM, Bleier BS, Scangas GA. Suction mitigation of airborne particulate generated during sinonasal drilling and cautery. Int Forum Allergy Rhinol. 2020 Oct;10(10):1136-1140.
21. Sharma D, Ye MJ, Campiti VJ, Rubel KE, Higgins TS, Wu AW, Shipchandler TZ, Sim MW, Burgin SJ, Illing EA, Park JH, Ting JY. Mitigation of Aerosols Generated During Rhinologic Surgery: A Pandemic-Era Cadaveric Simulation. Otolaryngol Head Neck Surg. 2021 Feb;164(2):433-442.
22. Murr A, Lenze NR, Brown WC, Gelpi MW, Ebert CS Jr, Senior BA, Thorp BD, Zanation AM, Kimple AJ. Quantification of Aerosol Particle Concentrations During Endoscopic Sinonasal Surgery in the Operating Room. Am J Rhinol Allergy. 2020 Oct 4:1945892420962335.
23. Sharma D, Campiti VJ, Ye MJ, Rubel KE, Higgins TS, Wu AW, Shipchandler TZ, Burgin SJ, Sim MW, Illing EA, Park JH, Ting JY. Aerosol generation during routine rhinologic surgeries and in-office procedures. Laryngoscope Investig Otolaryngol. 2021 Jan 14;6(1):49-57.
24. Dharmarajan H, Freiser ME, Sim E, Boorgu DSSK, Corcoran TE, Wang EW, Gardner PA, Snyderman CH. Droplet and Aerosol Generation With Endonasal Surgery: Methods to Mitigate Risk During the COVID-19 Pandemic. Otolaryngol Head Neck Surg. 2021 Feb;164(2):285-293.
25. Naik PP, Tsermoulas G, Paluzzi A, McClelland L, Ahmed SK. Endonasal surgery in the coronavirus era - Birmingham experience. J Laryngol Otol. 2020 Nov 4:1-4.
26. CRANIAL Consortium, Bandyopadhyay S, Khan DZ, Marcus HJ, Schroeder BE, Patel V, O'Donnell A, Ahmed S, Alalade AF, Ali AM, Allison C, Al-Barazi S, Al-Mahfoudh R, Amarouche M, Bahl A, Bennett D, Bhalla R, Bhatt P, Boukas A, Cabrilo I, Chadwick A, Chowdhury YA, Choi D, Cudlip SA, Donnelly N, Dorward NL, Dow G, Fountain DM, Grieve J, Giamouriadis A, Gilkes C, Gnanalingham K, Halliday J, Hanna B, Hayhurst C, Hempenstall J, Henderson D, Hossain-Ibrahim K, Hirst T, Hughes M, Javadpour M, Jenkins A, Kamel M, Mannion RJ, Kolias AG, Khan H, Khan MS, Lacy P, Mahmood S, Maratos E, Martin A, Mathad N, McAleavey P, Mendoza N, Millward CP, Mirza S, Muquit S, Murray D, Naik PP, Nair R, Nicholson C, Paluzzi A, Pathmanaban O, Paraskevopoulos D, Pollock J, Phillips N, Piper RJ, Ram B, Robertson I, Roman E, Ross P, Santarius T, Sayal P, Shapey

J, Sharma R, Shaw S, Shoakazemi A, Sinha S, Solomou G, Stapleton S, Statham P, Stew B, Shumon S, Soon WC, Thomas N, Tsermoulas G, Tysome JR, Varma A, Weir P, Williams A, Youssef M. CSF rhinorrhoea after endonasal intervention to the skull base (CRANIAL).: Part 2: Impact of COVID-19. World Neurosurg. 2021 Jan 11:S1878-8750(21)00013-9.

27. Taha MA, Hall CA, Rathbone RF, Corsten LA, Bowie CR, Waguespack PJ, Stanger R, Stevenson MM, Zito BA, Barham HP. Rhinologic Procedures in the Era of COVID-19: Health-care Provider Protection Protocol. Am J Rhinol Allergy. 2020 Jul;34(4):451-455.
28. Viera-Artiles J, Mato D, Valdiande JJ, Lobo D, Pedraja J, López-Higuera JM, Ospina J. A novel aerosolisation mitigation device for endoscopic sinus and skull base surgery in the COVID-19 era. Eur Arch Otorhinolaryngol. 2020 Nov 16:1–9.
29. Arefin MK, Arafat MS, Talukder DC, Rumi SNF, Islam MN, Rahman SH, Tarafder KH, Islam MA. 'POLIDON' Approach-A Novel Solution for the ENT & Skull Base Surgeons in COVID-19 era. Indian J Otolaryngol Head Neck Surg. 2020 Oct 18;73(1):1-5.
30. D'Amico RS, Khatri D, Kwan K, Baum G, Serulle Y, Silva D, Smith ML, Ellis JA, Levine M, Ortiz R, Langer DJ, Boockvar JA. Coronavirus Neurosurgical/Head and Neck Drape to Prevent Aerosolization of Coronavirus Disease 2019 (COVID-19): The Lenox Hill Hospital/Northwell Health Solution. World Neurosurg. 2020 Oct;142:314-317.
31. Maharaj SH. The nasal tent: an adjuvant for performing endoscopic endonasal surgery in the Covid era and beyond. Eur Arch Otorhinolaryngol. 2020 Oct;277(10):2929-2931.
32. Solari D, Bove I, Esposito F, Cappabianca P, Cavallo LM. The nose lid for the endoscopic endonasal procedures during COVID-19 era: technical note. Acta Neurochir (Wien). 2020 Oct;162(10):2335-2339.
33. Tsagkovits A, Ioannidis D, Rokade A. The microscope drape method to reduce aerosolisation during endoscopic sinus and skull base surgery in the COVID era. How i do it. Eur Arch Otorhinolaryngol. 2021 Feb;278(2):573-576.
34. Ioannidis D, Tsagkovits A, Rokade A. Minimising aerosol spread during endoscopic sinus and skull base surgery. Experimental model evaluation of the efficacy of the microscope drape method. J Laryngol Otol. 2020 Sep 14:1-7.
35. David AP, Jiam NT, Reither JM, Gurrola JG 2nd, Aghi MK, El-Sayed IH. Endoscopic skull base and transoral surgery during COVID-19 pandemic: Minimizing droplet spread with negative-pressure otolaryngology viral isolation drape. Head Neck. 2020 Jul;42(7):1577-1582.
36. Verreault D, Moineau S, Duchaine C. Methods for sampling of airborne viruses. Microbiol Mol Biol Rev. 2008;72(3):413-444.

Hosted file

`Figure 1.pdf` available at https://authorea.com/users/407814/articles/521333-one-year-into-the-covid-19-pandemic-what-do-we-know-so-far-from-studies-assessing-risk-and-mitigation-of-droplet-aerosolisation-during-endonasal-surgery-a-systematic-review

Hosted file

`Table.pdf` available at https://authorea.com/users/407814/articles/521333-one-year-into-the-covid-19-pandemic-what-do-we-know-so-far-from-studies-assessing-risk-and-mitigation-of-droplet-aerosolisation-during-endonasal-surgery-a-systematic-review