Minimizing the Risk of Aerosol Contamination During Elective Lung Resection Surgery

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Background: In the setting of the COVID-19 pandemic, the conduct of elective cancer surgery has become an issue because of the need to balance the requirement to treat patients with the possibility of transmission of the virus by asymptomatic carriers. A particular concern is the potential for viral transmission by way of aerosol which may be generated during perioperative care. There are currently no guidelines for the conduct of elective lung resection surgery in this context.

Methods: A working group composed of 1 thoracic surgeon, 2 anesthesiologists and 1 critical care specialist assessed the risk for aerosol during lung resection surgery and proposed steps for mitigation. After external review, a final draft was approved by the Committee for the Governance of Perioperative and Surgical Activities of the Hôpital Maisonneuve-Rosemont, in Montreal, Canada.

Results: The working group divided the risk for aerosol into 6 time-points: (1) intubation and extubation; (2) Lung isolation and patient positioning; (3) access to the chest; (4) conduct of the surgical procedure; (5) procedure termination and lung re-expansion; (6) chest drainage. Mitigating strategies were proposed for each time-point.

Conclusions: The situation with COVID-19 is an opportunity to re-evaluate operating room protocols both for the purposes of this pandemic and similar situations in the future. In the context of lung resection surgery, specific time points during the procedure seem to pose specific risks for the genesis of aerosol and thus should be the focus of attention.

Keywords: aerosol contamination, COVID-19, lung surgery

METHODS

Because of the need for expediency, a streamlined process was followed. A working group composed of 1 thoracic surgeon, 2 anesthesiologists, and 1 critical care specialist was assembled to identify time points during lung resection surgery that may present specific risks for the genesis of viral aerosol and to propose steps for mitigation. The draft proposal was referred for external review, and revisions were made based on the reviewers’ comments. The final draft was approved by the Committee for the Governance of Perioperative and Surgical Activities of the Hôpital Maisonneuve-Rosemont, in Montreal, Canada.

RESULTS

With respect to the risk of aerosol, the working group identified the requirement to establish single lung ventilation and the potential for perioperative air leak as the distinguishing features of lung resection surgery. Addressing these 2 issues was the guiding principle behind the working group’s recommendations, while recognizing the following caveats. Given the paucity of specific evidence, in some cases it was necessary to draw parallels with other areas of medical and surgical practice. In other cases, extrapolations were made from relevant basic science data. Finally, if no direct or indirect evidence was available, the working group made assumptions based on due consideration of the problems at hand and suggested solutions that seemed reasonable and practical. It is explicitly understood that the group’s recommendations are a baseline tool that is meant to be revised and elaborated with evolving experience and as new evidence becomes available. It is also meant to be flexible so that it can be adapted by other surgical teams to their specific circumstances.

Time-points

The working group divided the risks for aerosol into 6 time-points (Table 1).
1. Intubation and extubation.
2. Lung isolation and patient positioning.
3. Access to the chest.
4. Conduct of the surgical procedure.
5. Procedure termination and lung re-expansion.
6. Chest drainage.
Intubation and Extubation

Invasive airway manipulation is a major risk factor for infectious aerosol and detailed guidelines have been published. Although establishing single lung ventilation is not explicitly addressed, the extent of manipulations required may be expected to further increase the risk. There is no comparative data between double lumen tubes and bronchial blockers in this context; however, it is worth keeping in mind that double lumen tubes have been shown to be quicker to position, less likely to be incorrectly positioned, and less likely to cause airway complications. Guidelines also recommend that closed circuit ventilation should be strictly maintained; as a result, handling of airway tubing which involves or may involve a break in continuity should be done under apnea and without Positive End Expiratory Pressure/Continuous Positive Airway Pressure.

It is important to recognize that the risk of aerosol is particularly high during extubation because removal of a double-lumen tube or bronchial blocker can induce cough; appropriate cough suppression strategies should, therefore, be applied.

If airway manipulations are considered difficult or if at any point the patient is ventilated by face mask, aerosol contamination is considered to have occurred; the operating room should be closed off to all circulation until airborne contaminants have been removed, typically around 20 minutes, depending on the ventilation system.

Lung Isolation and Patient Positioning

To ensure closed circuit ventilation, any patient mobilization requires meticulous tube fixation and verification that all circuit connectors are tight; the patient should not be disconnected from the ventilator. The position of the endotracheal tube is double-checked bronchoscopically and the operated lung is isolated before surgical incision; it is recommended to connect a standard electrostatic filter to the corresponding lumen.

Access to the Chest

During surgical access to the chest, a breach in the visceral pleura and parenchyma may occur. Radionuclide imaging studies of pneumothorax suggest that particles as small as 5–10 nm may be released, which may be more significant if the underlying lung is subjected to positive pressure in the event of inadequate exclusion. The working group; therefore, recommended interrupting ventilation and using utmost care when opening the intercostal space or inserting an initial thoracoscopic trocar.

Conduct of the Surgical Procedure

During the actual surgical procedure, possible sources of biologic aerosol include smoke from the use of energy devices and secondary aerosol from fluid “splatter.” The nature of surgical smoke varies with the type of energy device and tissue, although data are incomplete and sometimes conflicting. As a general principle, energy may not be relied upon for the destruction of infectious agents, and tissue charring is more likely to release smaller particles and aerosolized pathogens. For this reason, it has been previously recommended that energy devices should be used sparingly and at low intensity, and advanced bipolar cautery or ultrasonic devices should be preferred over standard cautery.

Smoke from an open surgical field may be evacuated using dedicated, commercially available suction devices. During minimally invasive surgery, accumulation within a closed space may lead to a high concentration of smoke with pressurization and the potential for sudden discharge. This can be mitigated by periodically venting the surgical field, ensuring complete paralysis to avoid cough and forceful abdominal contractions, and, if applicable, using airtight laparoscopic trocars or trocars with built-in or add-on filters.

Laparoscopy guidelines also suggest minimizing CO₂ insufflation pressure, so in the case of lung surgery, CO₂ insufflation is likely best avoided. Because minimally invasive surgery does afford some possibility of smoke containment and more control over smoke evacuation compared to open surgery, the net effect of surgical approach (open or minimally invasive), at least in the case of laparoscopy, is unresolved. The working group considered that smoke control should be considered a multilayered process because each individual method has potential benefits and limitations, and
that surgical teams should, therefore, draft their specific protocols accordingly.\textsuperscript{3,6,7} “Splatter” can be reduced by ensuring optimal hemostasis (especially at trocar sites) and handling tissues and instruments with care.\textsuperscript{22} Laparoscopy guidelines recommend particular care with specimen extraction and trocar removal.\textsuperscript{24}

**Procedure Termination and Lung Re-expansion**

The working group emphasized the importance of air leak prevention, because pleural tears and parenchymal staple lines may leak air and generate aerosol when the lung is re-expanded under positive pressure.\textsuperscript{19–23} Although their efficacy is somewhat controversial, the use of tissue reinforcement and/or tissue sealants may be considered to promote staple line integrity,\textsuperscript{8,25–31} as can limiting ventilation pressures because some evidence suggests this may reduce strain on staple lines.\textsuperscript{31,32}

Nevertheless, because the potential for air leak is inherent to lung surgery, the working group suggested that lung re-expansion proceed only once the pleural cavity has been excluded from the operating room environment. We adopted a straightforward solution consisting of the 3 steps below, but any alternative that respects the underlying principle should be acceptable.

- **Closure of all incisions, except for the camera and the chest tube.** An air-tight trocar is used for the camera. The subcutaneous tissue and skin are closed around the chest tube in an airtight manner, and the tube is connected to an appropriate drainage system (see point 6). In the event of thoracotomy, the thoracotomy is closed and an extra incision is used for a camera trocar.
- **Negative pressure lung re-expansion.** The lung is re-expanded by applying moderate suction (−20 cm H\textsubscript{2}O) to the chest drainage system, under thorascopic visualization.
- **Closure of the remaining camera port.** Once lung expansion is deemed adequate, the camera and trocar are removed, and the remaining incision is closed before resuming ventilation.

The advantage of proceeding in this way is that there is no positive pressure ventilation on the operated lung at any time from incision to closure, minimizing the potential for miscommunication and error.

**Chest Drainage System**

Air evacuated from the pleural cavity is discharged into ambient air through the chest drainage system. We have found that it is possible to fit a standard electrostatic filter used in ventilator circuits onto standard chest drainage systems by adapting available tubing. Such filters remove 99.99\% of Hepatitis B Virus and Hepatitis C Virus which have a smaller diameter than SARS-COV-2 (70–90 nm).\textsuperscript{24} Although digital systems are equipped with filters, the working group was unable to verify whether these filters met objective standards required for preventing viral contamination through aerosol. Thus, chest tube drainage systems should be used with discretion, possibly in consultation with the manufacturer.

**Special Situations**

One potentially difficult problem is the inability to establish single lung ventilation, or the loss of single lung ventilation during the course of a procedure. Possible solutions may include attempts at re-establishing single lung ventilation, deferring, or even interrupting a procedure. Data are insufficient to make any recommendations although our preference is to defer any elective procedure if establishing single lung ventilation was not possible. Thoracic surgery teams should certainly prepare for this eventuality and plan their local protocols accordingly.

**CONCLUSIONS**

The situation with COVID-19 is an opportunity to re-evaluate operating room protocols both for the purposes of this pandemic and similar situations in the future. In the context of lung resection surgery, specific time points during the procedure may pose specific risks for the genesis of aerosol and should be the focus of attention. We have endeavored to outline ways to mitigate these risks and we encourage thoracic surgery teams to consider and adapt these recommendations to their specific circumstances. The need for continued re-evaluation in the context of a rapidly evolving situation cannot be over-stated.

**REFERENCES**

1. Wong J, Goh QY, Tan Z, et al. Preventing COVID-19 transmission from surgical smoke at the operating room: a review. *Can J Anaesth*. 2020. doi:10.1007/s12300-020-01620-9. [Epub ahead of print].
2. Li R, Pei S, Chen B, et al. Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV-2). *Science*. 2020. doi:10.1126/science.abb3221. [Epub ahead of print].
3. KwaK HD, Kim SH, SeoYS, et al. Detecting hepatitis B virus in surgical smoke emitted during laparoscopic surgery. *Occup Environ Med*. 2016;73:857–863.
4. Choi SH, Choi DH, Kang DH, et al. Activated carbon fiber filters could reduce the risk of surgical smoke exposure during laparoscopic surgery: application of volatile organic compounds. *Surg Endosc*. 2018;32:4290–4298.
5. Hensman C, Baty D, Willis RG, et al. Chemical composition of smoke produced by high-frequency electrosurgery in a closed gaseous environment. *An in vitro study*. *Surg Endosc*. 1998;12:1017–1019.
6. Park SM, Sohn DY, Kim IK, et al. Experimental study of the potential hazards of surgical smoke from powered instruments. *Br J Surg*. 2015;102:1581–1586.
7. Okoshi K, Kobayashi K, Kinoshita K, et al. Health risks associated with exposure to surgical smoke for surgeons and operation room personnel. *Surg Today*. 2015;45:957–965.
8. Heinsohn P, Jewett DL. Exposure to blood-containing aerosols in the operating room: a preliminary study. *Am Ind Hyg Assoc J*. 1993;54:446–453.
9. 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.
10. Government of Canada Public Health Services. Infection Prevention and Control for COVID-19: Second Interim Guidance for Agile Healthcare Settings. Available at: [https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/health-professionals/infection-prevention-control-covid-19-second-interim-guidance.html](https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/health-professionals/infection-prevention-control-covid-19-second-interim-guidance.html). Accessed 01 May 2020.
11. Technegas/Plus Technegas Generator; Cyclomedica Australia Pty Ltd (King-sgrove, Australia) [Product Monograph]. Available at: [https://compendium.chlwir/p/tetley-technegas-generator/mpro. Accessed 01 May 2020.](http://compendium.chlwir/p/tetley-technegas-generator/mpro)
12. Tran K, Cimon K, Severn M, et al. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. *PLoS One*. 2012;7:e35797.
13. Wax RS, Christian MD. Practical recommendations for critical care and anesthesiology teams caring for novel coronavirus (2019-nCoV) patients. *Can J Anaesth*. 2020;67:568–576.
14. Pang PWH, Ho PL, Hota SS. Outbreak of a new coronavirus: what anaesthesiists should know. *Br J Anaesth*. 2020;124:497–501.
15. Brewster DJ, Chimes NC, Do TB, et al. Consensus statement: Safe Airway anesthesiology teams caring for novel coronavirus (2019-nCoV) patients. *Can J Anaesth*. 2020;124:497–501.
16. Clayton-Smith A, Bennett K, Alston RP, et al. A comparison of the efficacy and adverse effects of double-lumen endobronchial tubes and bronchial blockers in thoracic surgery: a systematic review and meta-analysis of randomized controlled trials. *J Cardiothorac Vasc Anesth*. 2015;29:955–966.
17. D’Silva DF, McCulloch TJ, Lim JS, et al. Exubation of patients with COVID-19. *Br J Anaesth*. 2020. doi:10.1016/j.bja.2020.03.016. [Epub ahead of print].
18. Casha AR, Bertolacini L, Camilliet L, et al. Pathophysiological mechanism of post-obstructive air leaks. *J Thorac Dis*. 2018;10:3689–3700.
19. Nakanishi K, Shimotakahara A, Asato Y, et al. A new method to detect air leakage in a patient with pneumothorax using saline solution and multi-detector-row spiral CT scan. *Chest*. 2013;144:940–946.
20. Mark JB, McDougall IR. Diagnosis and localization of bronchopulmonary air leaks using ventilation scintigraphy. *Chest*. 1997;111:286–289.

21. Ceulemans G, De Meire L, Keyaerts M, et al. Air leaks localized with lung ventilation SPECT. *Clin Nucl Med*. 2012;37:1182–1183.

22. Unterreiner N, Weiss PE. Diagnosis of an air leak by radiolucide scan. *Clin Nucl Med*. 2001;26:1039.

23. Ono CR, Tedde ML, Scordamaglio PR, et al. Pulmonary inhalation-perfusion scintigraphy in the evaluation of bronchoscopic treatment of bronchopleural fistula. *Radiol Bras*. 2018;51:385–390.

24. Mintz Y, Arezzo A, Boni L, et al. A low cost, safe and effective method for smoke evacuation in laparoscopic surgery for suspected coronavirus patients. *Ann Surg*. 2020. doi:10.1097/SLA.0000000000003965. [Epub ahead of print].

25. Ha HI, Choi MC, Jung SG, et al. Chemicals in surgical smoke and the efficiency of built-in-filter ports. *JSLS*. 2019;23:e2019.00037.

26. Hahn KY, Kang DW, Azman ZAM, et al. Removal of hazardous surgical smoke using a built-in-filter trocar: a study in laparoscopic rectal resection. *Surg Laparosc Endosc Percutan Tech*. 2017;27:341–345.

27. Zheng MH, Boni L, Fingerhut A. Minimally invasive surgery and the novel coronavirus outbreak: lessons learned in China and Italy. *Ann Surg*. 2020;26. doi:10.1097/SLA.0000000000003924. [Epub ahead of print].

28. Choi SH, Kwon TG, Chung SK, et al. Surgical smoke may be a biohazard to surgeons performing laparoscopic surgery. *Surg Endosc*. 2014;28:2374–2380.

29. Malapert G, Hanna HA, Pages PB, et al. Surgical sealant for the prevention of prolonged air leak after lung resection: meta-analysis. *Ann Thorac Surg*. 2010;90:1779–1785.

30. Deguchi H, Tomoyasu M, Shigeeda W, et al. Reduction of air leakage using linear staple device with bioabsorbable polyglycolic acid felt for pulmonary lobectomy. *Gen Thorac Cardiovasc Surg*. 2020;68:266–272.

31. Drahush N, Miller AD, Smith JS, et al. Standardized approach to prolonged air leak reduction after pulmonary resection. *Ann Thorac Surg*. 2016;101:2097–2101.

32. Imhoff DJ, Monnet E. Inflation pressures for ex vivo lung biopsies after application of graduated compression staples. *Vet Surg*. 2016;45:79–82.