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

(*Ann Surg* 2020;272:e125–e128)

In the setting of the COVID-19 (SARS-CoV-2) 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,[1] which may account for up to 80% of infections.[2] A particular concern is the potential for viral transmission by way of aerosol which may be generated during perioperative care.[1,3–8] Aerosol refers to particles smaller than 1,0 micrometer in size for which standard operating room attire, including surgical masks, does not provide adequate protection.[3,7] Furthermore, aerosolized COVID-19 virus may remain viable on surfaces for prolonged periods.[9] To our knowledge, guidelines for the practice of lung surgery in this context are nonexistent.

Given the current situation and the requirement to maintain oncologic lung surgery in otherwise asymptomatic patients, an in-hospital working group was mandated with drafting recommendations for the perioperative management of elective lung resection surgery to minimize the risk of aerosol contamination in the operating room.

The authors recognize that risk mitigation involves several layers of intervention and that the most effective measure is risk elimination.[1] Thus elective surgery should be delayed or equivalent alternatives should be considered, if possible.[1] The following document deals only and specifically with the conduct of intraoperative care for patients for whom surgery was deemed the only option.

METHODS

Because of the need for expediency, a streamlined process was followed. A working group composed of 1 thoracic surgeon, 2 anesthetists, 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.

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This work did not receive any funding or support.

The authors report no conflicts of interest.

ISSN: 0003-4932/20/27202-e125

DOI: 10.1097/SLA.0000000000004087

TABLE 1. Proposed Procedures for Elective Lung Resection Surgery to Minimize the Risk of Aerosol Contamination in the Operating Room

Intubation and extubation	• Rapid sequence induction. • Avoid high flow O_2 or mask ventilation. • Apnea and **no** PEEP/CPAP before any tube disconnection. • Suppress cough.
Lung isolation and patient positioning	• Fix tube and ensure tight-fitting connections. • Double check tube position under apnea and **no** PEEP/CPAP • Connect electrostatic filter to operative lung lumen.
Access to the chest	• Interrupt ventilation before incision. • Access with care, especially if thoracoscopic trocar. • Resume single lung ventilation when lung integrity and adequate lung exclusion are confirmed.
Conduct of surgical procedure	**Recognize potential risk of surgical smoke and liquid « splatter ».** • Use energy sparingly, at low power. • Prefer advanced bipolar or ultrasonic to simple cautery. • Use smoke evacuation system and vent operative field periodically. • Consider airtight trocars (if applicable) with filters. • Ensure adequate paralysis. • Handle tissues with care, ensure hemostasis. **Recognize importance of air leak prevention.** • Handle lung with care. • Consider staple line reinforcement, sealants. • Avoid barotrauma to staple lines.
Procedure termination and lung re-expansion	• Exclude pleural space from operating room environment. • Consider using negative pressure lung re-expansion. • Re-ventilate surgical side after the chest has been closed.
Chest drainage	• Use standard chest drainage system fitted with an electrostatic filter or digital drainage system. • Consider consultation with the manufacturer(s).

Intubation and Extubation

Invasive airway manipulation is a major risk factor for infectious aerosol and detailed guidelines have been published.[10–15] 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.[16] 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.[10–12,15]

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[15,17]; appropriate cough suppression strategies should, therefore, be applied.[15,17]

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[15]; 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.[7,15]

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.[10–12,15] 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.[13–15]

Access to the Chest

During surgical access to the chest, a breach in the visceral pleura and parenchyma may occur. Radionucleide imaging studies of pneumothorax suggest that particles as small as 5–10 nm may be released,[11,18–23] 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[3–8] and secondary aerosol from fluid ''splatter.''[8] The nature of surgical smoke varies with the type of energy device and tissue, although data are incomplete and sometimes conflicting.[3,6,7,24–26] 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.[5,7,27] 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.[5,7,27] Smoke from an open surgical field may be evacuated using dedicated, commercially available suction devices.[3,7,24–26] 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.[4,28] This can be mitigated by periodically venting the surgical field, ensuring complete paralysis to avoid cough and forceful abdominal contractions,[4,28] and, if applicable, using airtight laparoscopic trocars or trocars with built-in or add-on filters.[4,25,26] Laparoscopy guidelines also suggest minimizing CO_2 insufflation pressure, so in the case of lung surgery, CO_2 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,[4,24] the net effect of surgical approach (open or minimally invasive), at least in the case of laparoscopy, is unresolved.[4,24] 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.[4,6,7] "Splatter" can be reduced by ensuring optimal hemostasis (especially at trocar sites) and handling tissues and instruments with care.[27] Laparoscopy guidelines recommend particular care with specimen extraction and trocar removal.[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.[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,[18,29–31] as can limiting ventilation pressures because some evidence suggests this may reduce strain on staple lines.[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 airtight 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_20) to the chest drainage system, under thoracoscopic 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).[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.

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