Brief Opinion

An Integrated Program in a Pandemic: Johns Hopkins Radiation Oncology Department

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Introduction

The presence of the novel coronavirus (COVID-19) pandemic1 prompted a structured response across the Johns Hopkins integrated network of radiation oncology facilities in Maryland and the District of Columbia. The department has developed a comprehensive reference document that serves as a resource for our staff and a summary of our response to the pandemic. The document in full has been posted on the American Society for Radiation Oncology “ROhub” web page.2 We present here several excerpts from the overall program document that we believe may be of interest and can serve as a resource to the radiation oncology community at large. These recommendations are based on current or projected conditions in the Maryland-DC region as of March 25, 2020, and are expected to evolve on an ongoing basis.

Patient treatment priority scales

Attempts should be made to determine whether the risks of pandemic infection outweigh the risks of delaying treatment for that individual patient at the time of consultation. It should be noted that a delay in instituting radiation treatment should be as short as possible. Evidence suggests that even for cancers with typically favorable outcomes, there are higher risk subgroups for whom delays may be detrimental,3,4 so the decision rests on an assessment of relative risks for an individual patient. Patients receiving care in 2 different centers (eg, external beam at one and brachytherapy at another) should receive special consideration.

Patients will be prioritized for radiation treatment based on the following priority scale, which was adapted from a general framework outlined by Ontario Heath-Cancer Care Ontario5:

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If a patient becomes a PUI,6 the following processes will be followed:

- If the patient is on treatment, the patient will be managed as presumptively positive.
- A treatment break should begin and last until the test result has become available.
- Once a negative result has been obtained, treatment may be resumed.
- PUI designated as level 1 may continue treatment and will be managed as COVID+ until proven otherwise, as described below.
- Patients and visitors (if present; only allowed in cases of necessity) should wear a surgical mask when in the health care facility.

Management of COVID+ patients (including level 1 PUI)

Inpatients: COVID+ inpatients will not be treated with radiation therapy until further notice, with decisions made on a case-by-case basis.

Outpatients: Outpatients who are COVID+ or live in the same household as someone who is COVID+ will also be treated as presumptive positive.

- If a COVID+ patient is receiving palliative radiation therapy and the clinical team determines that there is an acceptable medical alternative, radiation treatment can be discontinued at the discretion of the treating physician.
- COVID+ patients will only be treated if they are categorized as level 1.
- Patients should be moved to end-of-day treatment. This should continue for 14 days after positive diagnostic test and 7 days after resolution of symptoms, whichever is longer. Given that the duration of contagiousness of patients who have recovered from COVID-19 is unknown at this time, patients who resume treatment after a break necessitated by COVID-19 infection will also be treated at the end of the day on a single linear accelerator.
- No visitors are permitted, with rare exceptions made for caregivers of the severely impaired.
- Patients should wear surgical masks.
- Patients should enter the facility via a low-volume entrance and move to a dedicated isolation room while waiting for treatment (not in the waiting room). This isolation room should not be used by other oncology patients for the rest of the day.
- Staff should wear appropriate protective equipment (droplet and airborne precautions), which includes double gloves, nonpermeable gown, and a PAPR or fitted N95 with face shield.
- Multiple patients who are COVID+ will be treated sequentially on 1 machine at the end of the business day in each center rather than on multiple machines.
- Because COVID+ patients will be treated at the end of the day and staff will be following best practices to minimize exposure, we have not specifically prohibited staff from rotating to other machines, although this will be avoided when possible.
- Follow-up patient visits should be deferred for at least 2 weeks if feasible. This must be documented in the electronic medical record.

Management of PUI

If a patient becomes a PUI,6 the following processes will be followed:

- If the patient is on treatment, the patient will be managed as presumptively positive.
- A treatment break should begin and last until the test result has become available.
- Once a negative result has been obtained, treatment may be resumed.
- PUI designated as level 1 may continue treatment and will be managed as COVID+ until proven otherwise, as described below.
- Patients and visitors (if present; only allowed in cases of necessity) should wear a surgical mask when in the health care facility.
| Disease-specific priority scales (COVID-negative patients) | Level 1 (continue radiation) | Level 2 (short delay of radiation if needed) | Level 3 (consider holding radiation) |
|------------------------------------------------------------|-----------------------------|---------------------------------------------|-------------------------------------|
| **Breast** (see Appendix E1 for more detailed breast guidelines) | Nonmetastatic inflammatory breast cancer | All other breast cancer not meeting levels 1 and 3 | Patients meeting CALBG/PRIME II criteria for omission of radiation therapy |
| | Locoregional disease progressing through chemotherapy | | ER+ DCIS for patients meeting criteria from RTOG 9804, particularly if they can take hormone therapy |
| | | | Asymptomatic meningioma, pituitary adenoma, craniopharyngioma, pilocytic astrocytoma |
| | | | Asymptomatic low-grade glioma after gross total resection |
| | | | Trigeminal neuralgia |
| | | | Schwannomas |
| **Central nervous system** | High-grade gliomas of brain and spine tumors | Symptomatic low-grade glioma | Asymptomatic meningioma, pituitary adenoma, craniopharyngioma, pilocytic astrocytoma |
| | Benign or other tumors causing or with immediate threat of progressive neurologic symptoms | Cases where chemotherapy may permit delay of radiation | Asymptomatic low-grade glioma |
| | | | after gross total resection |
| | | | Trigeminal neuralgia |
| | | | Schwannomas |
| **Gastrointestinal** | Curative-intent anal, esophageal, and gallbladder/bile duct cancers | Neoadjuvant/adjuvant pancreas and rectal cancer treatment courses | None |
| | Curative-intent rectal cancer that is medically inoperable | | |
| | Curative-intent bladder cancers | | |
| | High-grade prostate cancer not able to receive androgen deprivation | | |
| | Genitourinary small cell carcinoma treated with curative intent | | |
| | Patients in middle of combined brachytherapy and external beam radiation therapy | | |
| | | | |
| **Genitourinary** | Curative-intent bladder cancers | All other curative-intent prostate cancers | None |
| | High-grade prostate cancer not able to receive androgen deprivation | Any cases of prostate cancer on androgen deprivation or low-risk prostate cancer cases that have not yet started radiation therapy can be triaged to the bottom of the level 2 patients |
| | Genitourinary small cell carcinoma treated with curative intent | | |
| | Patients in middle of combined brachytherapy and external beam radiation therapy | | |
| | | | |
| **Gynecologic** | Cervical cancer with severe bleeding | Postoperative vulvar cancer | Postoperative cases of endometrial cancer to be scheduled for induction chemotherapy or requiring vaginal brachytherapy alone (up to 4-8 wk postoperatively) |
| | Locally advanced vulvar or vaginal cancer causing severe pain | Inoperable endometrial cancer | |
| | | Postoperative cervical cancer (can be delayed up to 8 wk postoperatively) | |
| | | After induction chemotherapy, postoperative endometrial cancer (4-wk break allowed after chemotherapy) | |
| | | | |
| **Head/neck** | All curative cases where treatment with radiation therapy or concurrent chemoradiation is indicated | All curative cases where induction chemotherapy is deemed clinically appropriate | Keloids |
| | High-risk postoperative cases based on pathologic and intraoperative findings including recurrent well-differentiated extrathyroidal carcinomas | Intermediate-risk postoperative cases | Small COMS choroidal melanoma |
| | | Low-grade unresectable salivary gland malignancies | Asymptomatic glomus tumors |
| | | Recurrent parotid/skull base pleomorphic adenoma | Slow-growing small basal cell carcinoma with mild or no symptoms, in a patient age >70 y |
| | | Medium to large COMS choroidal melanoma or symptomatic choroidal melanoma | Asymptomatic cutaneous nonpigmented carcinomas located in low-risk anatomic regions |

(continued on next page)
Table 1 (continued)

| Disease-specific priority scales (COVID-negative patients) | Level 1 (continue radiation) | Level 2 (short delay of radiation if needed) | Level 3 (consider holding radiation) |
|-------------------------------------------------------------|------------------------------|---------------------------------------------|------------------------------------|

Lymphoma

- Patients with high-grade lymphomas with severe or life-threatening symptoms
- Cord compression from histology other than chemotherapy-naïve small cell lung cancer or lymphoma and not amenable to surgical decompression
- Symptomatic brain metastases not amenable to surgical decompression or brain metastases >5 mm from histologies not anticipated to respond to systemic therapy
- Malignant airway obstruction not amenable to surgical intervention/stenting
- SVC syndrome not amenable to thrombectomy/stenting
- Acute hemorrhage from primary or metastatic disease not amenable to embolization/other direct intervention
- Severe pain from primary or metastatic disease not responding to conservative measures
- Heterotopic bone (at discretion of doctor)

Palliative

- Consolidation therapy for high-grade lymphomas
- Painful spine metastasis without epidural extension or other immediate risk to the neuraxis
- Spinal cord compression or spine metastases with epidural disease in patient with chemotherapy-naïve small cell lung cancer or lymphoma who can receive chemotherapy
- Brain metastases <5 mm anticipated to be responsive to targeted agents or immunotherapy
- Other metastatic sites causing non—life-threatening symptoms, particularly those that may respond to conservative measures (eg, pain, shortness of breath stable on room air)
- Patients with stable or minimally symptomatic oligometastatic disease

Pediatrics

- All curable cases where delay of radiation is not possible
- All cases where chemotherapy or other interventions can be safely used to delay initiation of radiation therapy
- All elective or nonessential radiation cases

Sarcoma

- Palliation of extreme pain or uncontrolled bleeding
- All other neoadjuvant, adjuvant, and definitive cases
- None

Thoracic

- Limited-stage small cell lung cancer
- Consolidation of oligometastatic and oligoprogressive lung cancer
- Stage I NSCLC
- Postoperative thoracic tumors without residual disease
- Pulmonary ground glass opacities without solid component
- None

Abbreviations: CALGB = Cancer and Leukemia Group B; COMS = Collaborative Ocular Melanoma Study; ER+ = estrogen receptor positive; NSCLC = non small cell lung cancer; RTOG = Radiation Therapy Oncology Group; SVC = superior vena cava.
| Machine vault Measurement | Airflow exchange per hour | 99% exchange time (min) | 99.9% exchange time (min) |
|---------------------------|--------------------------|------------------------|--------------------------|
| Primary campus LINAC 1    | Actual                   | 10.07                  | 27.72                    | 41.14                    |
| Standard LINAC 2          | Actual                   | 5.94                   | 46.53                    | 69.97                    |
| Standard LINAC 3          | Actual                   | 5.83                   | 47.39                    | 71.30                    |
| Tomotherapy Actual        | 16.99                    | 16.60                  | 24.31                    |                          |
| Specialty stereotactic    | Actual                   | 7.63                   | 36.40                    | 54.39                    |
| Regional campus 1 All LINACs Minimum Actual | 12 | 23.34 | 34.49 | |
| Tomotherapy Minimum Actual | 10 | 27.91 | 41.43 | |
| All proton gantries Maximum Actual | 6 | 18.75 | 27.55 | |
| Regional campus 2 Standard LINAC Actual | 6.5 | 42.59 | 63.91 | |
| Regional campus 3 Standard LINAC Actual | 8 | 34.74 | 51.86 | |
| Regional campus 4 Standard LINAC Actual | 6.5 | 42.59 | 63.91 | |

Abbreviations: LINAC = linear accelerator; 99% = time for 99% airflow exchange; 99.9% = time for full (99.9%) airflow exchange.

* Actual measurements represent airflow measured under standard automatic temperature control and building automation systems settings. Minimum and maximum measurements represent the range of airflow rates delineated according room design specifications; these were not directly measured.

**Radiation treatment for patients recovering from COVID-19 infection**

Patients may resume treatment without COVID-19 precautions after meeting 1 of the 2 following criteria (extrapolated from the Centers for Disease Control and Prevention’s return-to-work criteria for health care personnel):

1. Test-based strategy:
   - Resolution of fever without the use of fever-reducing medications, and
   - Improvement in respiratory symptoms (e.g., cough, shortness of breath), and
   - Negative results on a Food and Drug Administration Emergency Use Authorized molecular assay for COVID-19 from at least 2 consecutive nasopharyngeal swab specimens collected ≥24 hours apart (total of 2 negative specimens).²

2. Non-test-based strategy:
   - At least 3 days (72 hours) have passed since recovery, defined as resolution of fever without the use of fever-reducing medications and improvement in respiratory symptoms (e.g., cough, shortness of breath); and
   - At least 7 days have passed since symptoms first appeared.

**Cleaning and equipment management**

**Cleaning of clinic and treatment areas**

During this period, we follow additional precautions above and beyond our normal processes for infection control, wherever possible. All equipment should be cleaned with greater frequency. All treatment areas should be cleaned with 70% alcohol, PDI Super Sani-Cloth, or other Hospital Epidemiology and Infection Control (HEIC)-approved cleaning solutions after each patient, including the linear accelerator couch, the simulator couch, and all door handles or any other items that patients touch routinely. All patients and providers should use hand sanitizer before and after entering the treatment vault. All examination and treatment spaces as well as common spaces within clinics and waiting rooms should undergo thorough cleaning with approved cleaner solutions at least twice a day. Cleaning should include but not be limited to countertops, chair armrests, and other non-fabric surfaces. Given additional risks associated with management of head and neck patients, our specific guidelines for this group are included in Appendix E2.

**Airflow exchanges on linear accelerator and proton vaults**

If COVID+/PUI patients are treated, full (99.9%) airflow exchange must occur before treatment of the general population during the next business day. To determine the times required for full airflow exchange in each treatment vault, these values were either directly measured by facility staff or estimated using the range of airflow rates from the room design specifications to extrapolate clearance levels. Table 2 summarizes the relevant airflow exchange times for the treatment vaults across our clinical sites. We used these data to select treatment vaults that were most appropriate for treating COVID+/PUI. For example, in a review of data for the East Baltimore site, full airflow exchange times for the vaults of our most versatile linear accelerators ranged from 41.1 to 71.3 minutes; thus, we selected the vault with the shortest exchange time for a treating future COVID+/PUI patients.

**Terminal cleaning**

After treatment of COVID+/PUI, terminal cleaning procedures must be performed in the machine vault before...
Active breathing coordinator procedures

Based on current information from manufacturers and product suppliers, our active breathing coordinator (ABC) system’s single-use mouth piece/tube with attached ViroMax filter has $>99.99\%$ filtration efficiency for viral particles and is reported to be effective for particles as small as 0.1 $\mu$m in size. Currently, we do not have information regarding filtration efficiency for particles $<0.1$ $\mu$m, and it has been noted that COVID-19 particles may vary in size from 0.06 to 0.14 $\mu$m. Although it may be assumed that the actual transmitting respiratory droplet size may be larger—and thus more effectively filtered—than individual viral particles themselves, the specific filtration efficiency across the range of COVID-19 particle size remains somewhat unclear.

In addition to this potential uncertainty, ABC is thought to be a higher-risk procedure for staff owing to possible exposure to saliva and respiratory droplets that may be spread during ABC procedures. Furthermore, it requires increased machine time and coordination between treatment machines when ABC systems are shared.

Given the information currently available, our procedure for ABC is as follows:

1. In general, no ABC use for COVID+, PUI, or those who screen positive for new respiratory symptoms. Treating physician can evaluate whether they believe that the respiratory symptoms are low risk for being due to COVID and make an individualized decision to proceed with ABC at physician discretion if so.

2. Future patients: Limit ABC use to patients (1) without COVID+/PUI status or new respiratory symptoms, and (2) for whom there is clear clinical necessity of ABC use. “Clinical necessity” should be determined at the discretion of the treating physician and based on consensus from disease site-specific providers (Table 3 summarizes the approved indications for the use of ABC by disease site).

3. Patients currently on treatment: Can continue with ABC as long as the patients does not have COVID+/PUI status or new respiratory symptoms. If current patients fall into this category and clinical necessity is determined by the treating doctor, ABC can continue as planned.

4. If on-treatment patients using ABC convert to COVID+ or PUI status, the ABC system should be removed from use in the general population. It will not be returned to use until cleared by HEIC. When shared between treatment machines, ABC system use should be tracked to permit for identification of potentially exposed patients in the setting of an

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**Table 3** Guidelines for use of active breathing coordinator

| Disease Site | ABC Use Guidelines |
|--------------|--------------------|
| Central nervous-system | For GI tumors susceptible to motion, 4DCT will be acquired. Treatment with free-breathing or abdominal-compression approach will be considered for all such patients. ABC is considered clinically necessary when treatment in free breathing or with abdominal compression leads to unacceptably high risk for toxicity (as defined by the treating doctor), and this risk would be substantially lowered with ABC. Specific considerations for the use of ABC include GI cases in which: |
| GI malignancies | - Expanded lung volumes with ABC will reduce the risk of lung injury for patients with mediastinal disease. |
| Lymphoma | Motion mitigation with ABC will lead to significant dose reductions in the abdomen or chest. In such cases, free-breathing or abdominal-compression approaches may be particularly useful alternatives. |
| Pediatric thoracic cancers | As per treatment guidelines for tumor location: ABC is clinically necessary for: |
| | - Any reirradiation case where the anticipated toxicity will be reduced with ABC. |
| | - Any conventionally fractionated case where a plan that meets minimum safety requirements cannot be achieved except with ABC. |
| | - Any hypofractionated or SABR plan that cannot meet normal tissue safety objectives or will not be well visualized on cone beam computed tomography without the use of ABC. |
| Sarcoma | As per treatment guidelines for tumor location: 4DCT will be acquired in patients large enough for tracing to be obtained when there is a concern for susceptibility to motion. ABC will be considered clinically necessary and will be used in cooperative patients where ABC significantly reduces dose to organs at risk. |
| Breast | ABC technique will be used very judiciously and be considered clinically necessary only in cases with cardiac mean dose $>4$ Gy or lung V20 $>40\%$ when free-breathing techniques are used. In general, we should seek alternative approaches to ABC, including IMRT/VMAT, to meet dose objectives. |

**Abbreviations:** 4DCT = 4-dimensional computed tomography; ABC = active breathing coordinator; GI = gastrointestinal; IMRT = intensity modulated radiation therapy; VMAT = volumetric modulated arc therapy.
on-treatment patient converting to PUI/COVID+ status (if required per HEIC).
5. If there are PUI/COVID+ patients who clinically require treatment with ABC and cannot be put on a treatment break, they will be treated on a separate ABC system designated for COVID+ use. This may require transfer of care to a site with multiple ABC systems.
6. A new single-use mouth piece and filter kit must be used per treatment per patient. No reuse of these parts is permitted at this time.

Clinical trials and laboratory research

Clinical trials will stop all new enrollments. The sole exceptions are prioritized trials where the trial is the only treatment option for the patient. Follow-up visits for trials will be conducted by phone whenever possible. Research specimens will not be collected unless there is a clear need, for patient safety. All laboratory research has been discontinued, and research staff are working and meeting remotely.

Conclusions

During this period of pandemic, additional considerations are necessary for prioritization of radiation treatment and equipment, as well as for additional infection control measures. The preceding represents selected considerations that we hope will be of value to the radiation oncology community as we navigate these unprecedented conditions.

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Supplementary materials

Supplementary material for this article can be found at https://doi.org/10.1016/j.adro.2020.03.014.

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