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Technical Report

Novel Use of Biphasic Cuirass Ventilation During Definitive Radiation Therapy: A Technical Report

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Abstract
The use of biphasic cuirass ventilator supported radiation therapy has never been documented. We present the first technical report here.

A 57-year-old man with obstructive sleep apnea presented with a T0N1M0 right sided, human papillomavirus related head and neck cancer diagnosed on excisional lymph node biopsy. On further workup, the cancer was found to have originated in the right tonsil and was staged as T1N1. The patient started definitive treatment with concurrent chemo-radiation therapy, but after 5 treatments was no longer able to lay in a supine position for treatment.

Diagnostic imaging workup eventually revealed an idiopathic right sided hemi-diaphragm eventration. After consultation with cardiology, pulmonology, and head and neck surgery, recommendation was made for tracheostomy to tolerate supine radiotherapy position, but the patient refused.

Instead, computed tomography simulation for radiotherapy replanning was performed using a combination of biphasic cuirass ventilation, home continuous positive airway pressure and oxygen. The patient then tolerated definitive treatment to a dose of 69.96 Gray in 33 fractions with concurrent chemotherapy and experienced no unexpected side effects. Although complex, daily treatment setup was consistent. Daily onboard imaging was precise and accurate. The patient continues to follow up with radiation oncology, medical oncology, and pulmonology.

This is the first use of biphasic cuirass ventilator supported radiotherapy reported in the scientific literature. Although daily treatment setup is complex, its use could be considered in patients unable to tolerate radiation therapy treatment positioning as an alternative to tracheostomy.

Introduction

Biphasic cuirass ventilation (BCV) refers to the use of a portable external thoracic shell that creates a seal around the anterior chest and generates both negative and positive pressure, which can assist with breathing. Various modes exist, including controlled biphasic ventilation, continuous negative pressure, and high frequency oscillation, all of which can be applied when traditional invasive methods of positive pressure ventilation are not possible.[1,2] Previously described applications include heart failure or lung disease requiring chest physiotherapy, acute respiratory failure to assist intubated patients in weaning from respiratory support, and respiratory

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compromise from neuro-muscular defects.[1,3] In the surgical realm, BCV has been used during microlaryngeal and tracheal procedures in lieu of intubation or intermittent apnea.[4-7] Despite this, BCV use has never been reported in the field of radiation oncology.

Herein, we describe the novel use of BCV in a patient who required radiation therapy for oropharyngeal cancer but could not tolerate lying in the supine position due to comorbid obstructive sleep apnea (OSA) and idiopathic hemi-diaphragmatic eventration.

Methods and Materials

Case presentation

A 57-year-old man with a history of OSA and central obesity (body mass index 35) presented for evaluation of an otherwise asymptomatic right neck mass. Computed tomography (CT) of his neck revealed multiple enlarged right sided cervical lymph nodes. Fine needle aspiration was nondiagnostic, necessitating excisional biopsy of a right sided level 3 lymph node. Pathology showed a p16 + squamous cell carcinoma (SCCa). Subsequent positron emission tomography (PET) scan showed additional right sided fluorodeoxyglucose avidity, but no primary site could be identified.

The patient underwent direct laryngoscopy and transoral robotic lingual tonsillectomy. No gross tumor was visualized; however, intraoperative biopsies of the right lingual tonsil confirmed SCCa. The patient was restaged as having T1N1M0 (American Joint Committee on Cancer 8th edition) p16 + SCCa of the oropharynx. He was presented at local tumor board and multimodal therapy was recommended.

Definitive chemo-radiation therapy began and the patient was tolerating treatment well. However, after 5 treatments and 2 days off over the weekend, the patient returned unable to tolerate supine treatment position for even a few seconds due to worsening orthopnea. This prevented him from lying flat at home, even when wearing his continuous positive airway pressure (CPAP) device.

Given the ongoing Corona Virus disease pandemic at the time, nasopharyngeal RNA testing was performed, for which results were negative. Due to his underlying OSA, he was referred to a surgical sleep specialist who fitted the patient with an oral appliance to optimize pharyngeal patency; however, it was unsuccessful in allowing him to lie supine. To rule out a cardio-pulmonary etiology, the patient was referred to a cardio-oncologist and pulmonologist for evaluation. Transthoracic echocardiogram did not reveal underlying cardiac pathology. An upright chest radiograph demonstrated eventration of the right hemi-diaphragm with associated atelectasis of the right lung. A compromised right phrenic nerve was suspected; however, fluoroscopic imaging demonstrated normal motion of the right diaphragm throughout respiratory phase during normal breathing and during a sniff test. Subsequent CT scan of the thorax performed with the patient in the prone position confirmed findings of an elevated hemi-diaphragm (Fig 1).

Given his continued delay in treatment, definitive surgical treatment versus tracheostomy placement was discussed. However, owing to presumed regional spread, further surgical resection would have likely necessitated adjuvant radiation. Furthermore, the patient wished to avoid a tracheostomy. A trial of cuirass ventilation was recommended as an alternative by the pulmonologist.

Results

Radiation therapy planning and treatment setup

After consultation with pulmonology, a regional BCV supply company representative educated the patient on use of the device and determined the treatment settings. A replanning CT simulation was planned as about 1 month had elapsed from the last radiation treatment. At the time of simulation, the company representative was present to educate the radiation therapy team on use of the BCV device. CT simulation using an immobilization mask was successful and radiation replanning was performed to a

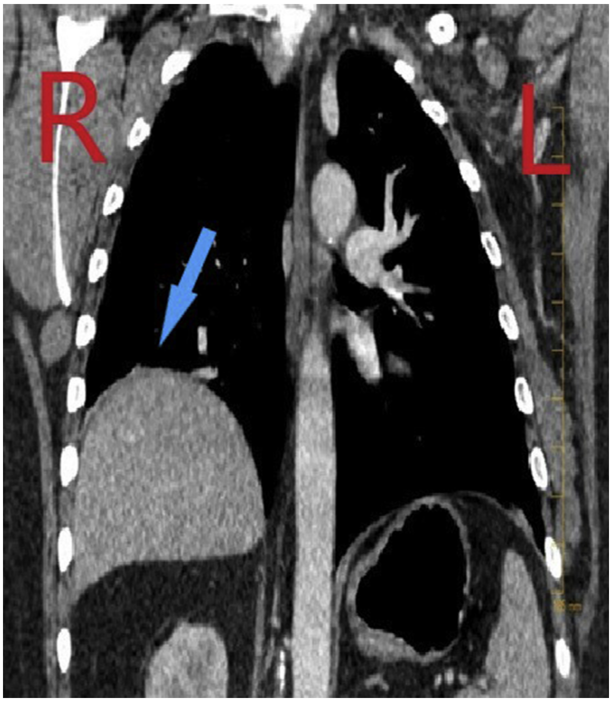

Figure 1 Coronal view of the diagnostic computed tomography (CT) scan, which identified an idiopathic right-sided hemidiaphragm eventration (blue arrow). This was the cause of the patient's inability to lie flat for radiation therapy.

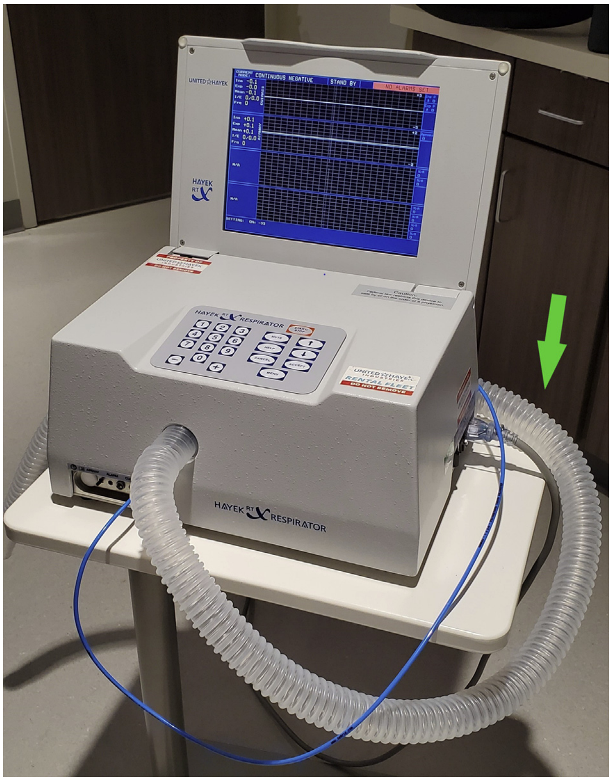

Figure 2 The biphasic cuirass ventilation (BCV) machine. The thin blue opaque tube (unmarked) and the larger ridged clear tube (green arrow) are connected to the cuirass shell seen in Figures 4 and 5.

total dose of 69.96 Gy in 33 fxn, taking into account the previous 5 fxn of radiation therapy. All institutional target coverage goals and organ at risk dose constraints were met using intensity modulated radiation therapy matched to a lower neck 3-dimensional field.

Daily radiation therapy treatment setup was performed by 2 radiation therapists and the supervising radiation oncologist. Daily setup was consistent with total setup and treatment time being about 30 minutes. The daily treatment setup was carried out as follows:

1. Before the patient entered the room, the ventilator (Fig 2) was preset to the “continuous negative extrathoracic pressure” setting with a maximum inspiratory pressure of −35 cm H20. This increased functional residual capacity, which allowed the patient to maintain supine treatment position while also maintaining synchrony with his natural breathing cycle.
2. The home CPAP machine was connected to the wall oxygen delivery unit via a specially designed bifurcation valve (Fig 3). The rate of oxygen flow was 3 to 5 L/min. The patient then applied the CPAP nasal prongs while in a standing position at a pressure setting of 10 cm H20.
3. A size 10 cuirass shell was placed over the abdomen/chest and air leakage was prevented using a preattached seal. The shell was then connected to the ventilation device using connection tubes. The ventilation machine was turned on and once the negative pressure ventilation was started, 2 large Velcro straps were secured in place to prevent shell movement (Fig 4). The patient then laid down on the treatment table (Fig 5).
4. Bolus was placed over the right sided excisional biopsy scar. The CPAP tube was disconnected for a few seconds to allow for placement of the immobilization mask. The mask was then secured to the treatment table.
5. The CPAP tubing was taped out of the treatment field to maintain consistent daily dose delivery (Fig 6).
6. Treatment was delivered after using 6-dimensional couch correction based on localization from daily onboard cone beam CT imaging.
7. After treatment was delivered, the radiation therapists conducted daily quality assurance measurements before the patient got off the treatment table.

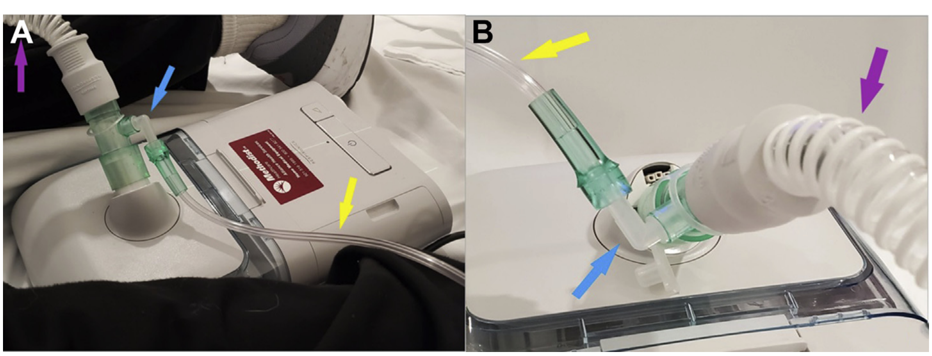

Figure 3 (A,B) The patient’s home continuous positive airway pressure (CPAP) machine used during daily radiation therapy set-up and treatment. The largest tube (purple arrow) delivered CPAP at a pressure of 10 cm H20 to the patient’s nasal prongs (seen in Figs 4 and 6). The transparent thin tube was connected to a wall unit and delivered oxygen at a rate of 3 to 5 L per minute. The custom bifurcation valve allowed mixing of CPAP and oxygen (blue arrow).

Figure 4 The patient in a standing position holding the cuirass shell over his abdomen/chest. The thin blue tube (unmarked) and thick ridged tube (green arrow) connected to the biphasic cuirass ventilation (BCV) device seen in Figure 2. The medium sized tube (purple arrow) joined the nasal prongs to the home continuous positive airway pressure (CPAP) unit seen in Figure 3.

8. The CPAP tubing was once again briefly disconnected to allow for removal of the immobilization mask and scar bolus.
9. The ventilator machine was turned off, just before the 2 Velcro straps and cuirass shell were removed. The patient was then able to quickly sit up.

Treatment course was uneventful over a period of 7 weeks. From a side effect standpoint, there were no unexpected acute radiation side effects. Due to dysgeusia, the patient had been on a full fluid diet since his initial surgery and continued to lose weight throughout radiation therapy, losing a total of about 12 pounds. He otherwise had minor odynophagia and skin erythema. At the end of treatment, the patient was still unable to lie in a supine position for more than a few seconds without BCV assistance. He will continue follow-up with pulmonology and radiation oncology moving forward.

Discussion

We report the first case of BCV assisted radiation therapy for a curable head and neck malignancy, demonstrating its viability as a management option.

Lack of reported BCV use in this setting is likely due to the relative rarity of patients who are unable to tolerate lying in a supine position, which prevents consistent daily radiation therapy delivery. It may also be due to the relatively common use of tracheostomy. In this case, an elevated hemi-diaphragm causing poor right sided lung ventilation exacerbated by the patient's pre-existing OSA and central obesity, is the likely medical culprit.

At the time of this publication, the precise etiology of the patient's diaphragmatic pathology remains unclear, despite extensive medical evaluation. It is implausible that his phrenic nerve was damaged during the course of either of his 2 original surgical operations given the timing of the new onset of orthopnea. Another previously documented possibility is that a maneuver performed by his chiropractor resulted in a phrenic neuropraxia, which is more consistent with the time course of this presentation.[8,9]

Desire to avoid tracheostomy and associated side effects may lead to consideration of BCV during radiation therapy. Other potential advantages include maintenance of physiological humidification and filtration of the upper airways as well as preservation of oral nutrient intake. BCV can be delivered as an outpatient procedure, eliminating the complexity and cost of inpatient admission. Potential disadvantages include a steep learning curve given the relative inexperience of radiation oncology departments in administering BCV. Finally, BCV assisted radiation therapy can be used to treat head and neck,

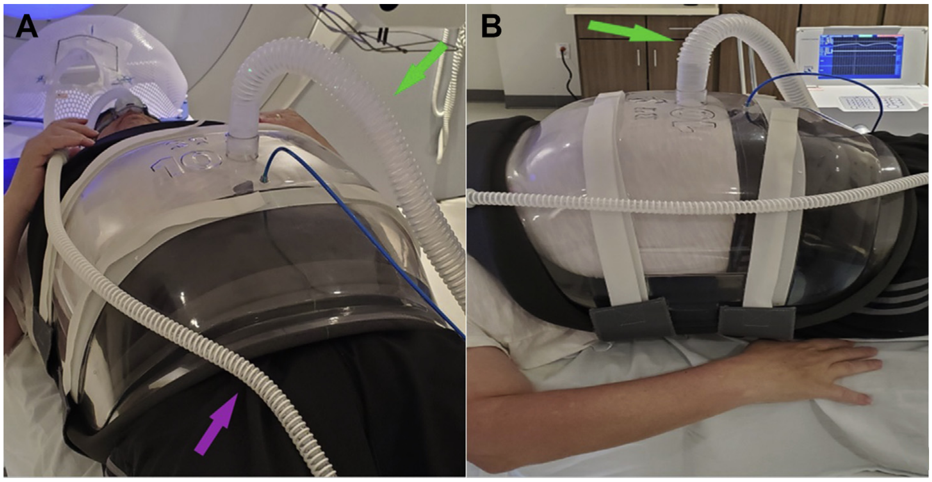

Figure 5 (A,B) Supine view of the patient wearing the cuirass shell before treatment. Again, the thin blue tube (unmarked) and thick ridged tube (green arrow) connected to the biphasic cuirass ventilation (BCV) device seen in Figures 2 and 5B, while the medium sized tube (purple arrow) connected the nasal prongs to the home continuous positive airway pressure (CPAP) machine seen in Figure 3.

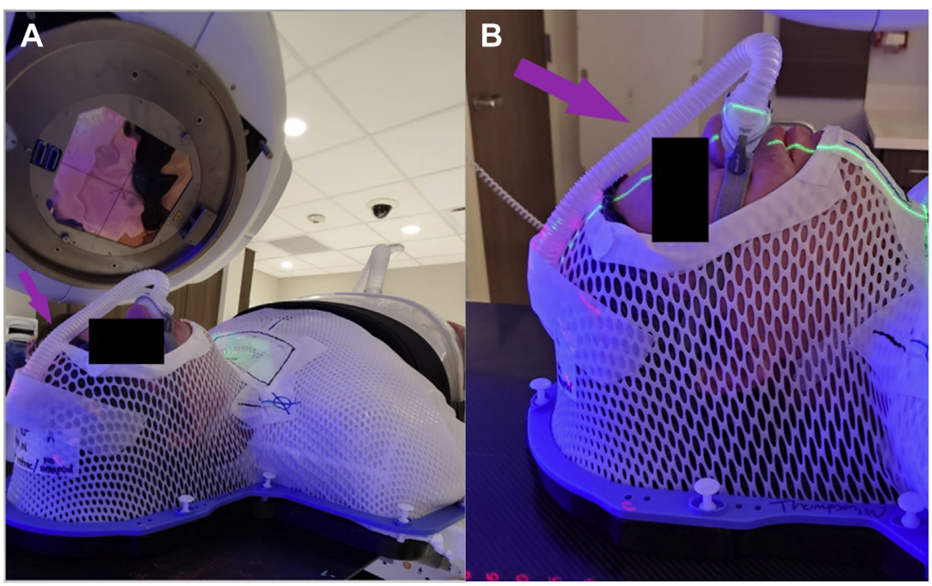

Figure 6 (A,B) Supine view of the immobilization mask on the patient shows that the medium sized tube (purple arrow) has been taped out of the treatment field. The tube connects the nasal prongs to the home continuous positive airway pressure (CPAP) machine from Figure 3.

brain, and extremity cancers, but its use would be limited with thoracic or abdominopelvic malignancies given the placement of the cuirass shell.

Conclusions

In conclusion, we report the novel use of BCV assistance to treat a patient with curable head and neck cancer with definitive radiation therapy. A future clinical scenario with similar challenges or a desire to avoid invasive tracheostomy is likely. Our hope is that this publication increases awareness in our field of BCV assisted radiotherapy as an option for patients diagnosed with cancer.

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