Use of noninvasive positive pressure ventilation to improve the quality of conventional CT and CTPA

Radhika R. Akella, Naomi M. Kane, Thomas J. Donnelly

*Department of Medicine, Wright State University, Dayton, OH, USA
bDepartment of Radiology, Miami Valley Hospital, Dayton, OH, USA
cPulmonary and Critical Care Consultants, Inc., Dayton, OH, USA

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Summary

Pulmonary specialists are frequently asked to evaluate patients with equivocal findings on CT and CTPA. Inspiratory and expiratory images are invaluable, but some patients are unable to perform the required respiratory maneuvers adequately. Our cases demonstrate how the application of CPAP during imaging can clarify imaging for airway, parenchymal, and vascular findings. The improved images were critical to management decisions in these cases. While this technique is not necessary for most patients, it can be very helpful in selected cases.

Introduction

Conventional computed tomography (CT) and CT pulmonary angiography (CTPA) are routine studies used in the evaluation of pulmonary parenchymal disease, airway abnormalities and suspected pulmonary embolism. While quite useful, the studies have limitations when the quality is suboptimal. In our practice, we are frequently consulted to evaluate patients with equivocal findings on CT or CTPA. We have found that the image quality can be improved by the application of continuous positive airway pressure (CPAP) while performing the CT scan in selected cases. This technique is particularly useful when patients are unable to perform adequate breath-holding for inspiratory and expiratory images.
Expiratory CTs. The following cases are illustrative of the advantage of applying CPAP to improve the quality of CT or CTPA images.

**Intervention**

Patients selected for CPAP scans had equivocal CT or CTPA findings and were unable to perform adequate breath-holding for inspiratory and expiratory CT. Three patients were placed on CPAP for approximately 1 h prior to repeat scanning and remained on CPAP during the studies.

**Patients**

**Case #1**

A 61-year old morbidly obese woman was evaluated for shortness of breath, hypoxia, edema and suspected sleep apnea. She had been treated with high doses of steroids in the past without improvement. Examination demonstrated a morbidly obese woman on supplemental oxygen who had minimally reduced air entry bilaterally, but no significant wheezing. The patient’s arterial blood gases were as follows: pH 7.41, pCO2 68.6, bicarbonate 44.0, pO2 49.0 and an oxygen saturation of 83% on room air. A chest X-ray showed no infiltrates. Lower extremity Doppler studies were negative for the presence of deep venous thrombosis. Pulmonary function studies showed a moderate-to-severe restrictive type defect with no evidence of bronchodilator response. CTPA was performed and is shown in Figure 1a. This first study was limited by the patient’s body habitus, imaging artifact and poor visualization of the pulmonary vasculature. Suspected bibasilar atelectasis was noted and findings were suggestive of a mosaic type pattern. Because of the uncertainty of the findings on CT scan, high resolution CT scanning was attempted with inspiratory and expiratory views; however, the image quality was again sub optimal as the patient was unable to hold her breath adequately despite extensive coaching by staff. The third study was a conventional CT with contrast performed with the patient breathing spontaneously (Figures 1b and c) and then on CPAP of 6 cm H2O (Figures 1d and e). Images obtained off of CPAP show narrow caliber airways (Figure 1b) and a mosaic pattern with areas of relatively decreased lung attenuation alternating with areas of increased lung attenuation (Figure 1c). Images obtained on CPAP show larger caliber airways (Figure 1d) and decrease in the mosaic pattern (Figure 1e). These results confirm that the CT abnormalities were due to airway disease and not parenchymal lung disease or pulmonary vasculopathy.

**Case #2**

A 55-year old male presented with dyspnea, wheezing, chest congestion and a productive cough. The presentation was very typical of prior asthma exacerbations and bronchitis. The patient also had a history of massive pulmonary embolism and had been treated with one year of coumadin anticoagulation in the past. In the ER a CTPA was ordered and he was admitted to the hospital. The CTPA was of suboptimal quality, showing a narrow caliber trachea (Figure 2a), mainstem and segmental airway narrowing (Figure 2b) and a question of bilateral filling defects in some vessels in the lower lung zones (Figure 2c). He was treated empirically with anticoagulation for possible pulmonary embolus and also treated for an asthma exacerbation. The patient could not perform adequate breath-holding for inspiratory and expiratory CT. Our service was consulted and a repeat CTPA was performed with the patient on CPAP. Better quality images were obtained showing a larger caliber trachea (Figure 2d), larger mainstem and segmental airways (Figure 2e) and better opacification of the pulmonary vasculature with no evidence of pulmonary embolus (Figure 2f). The patient had negative lower extremity Doppler studies. Therapeutic anticoagulation was discontinued. He responded well to bronchodilators and steroid therapy and has remained well for over 2 years without signs or symptoms of recurrent dyspnea or pulmonary embolus.

**Case #3**

A 51-year old woman with a history of chronic obstructive pulmonary disease and active smoking was admitted to the hospital with an incarcerated hernia and underwent surgical repair. Postoperatively the patient was lethargic with evidence of CO2 retention while receiving narcotics. Her oxygen saturation was observed to be low and CTPA was ordered. The study was of suboptimal quality and showed marked tracheal narrowing (Figure 3a), a decrease in airway caliber (Figure 3b) as well as patchy airspace disease, a small pleural effusion and questionable filling defects in the pulmonary vasculature suggestive of pulmonary embolus (Figure 3c). The patient could not perform adequate breath-holding for inspiratory and expiratory CT. Because of the equivocal findings, our service was consulted and a repeat CTPA was performed with the patient on CPAP. This study showed a larger caliber trachea (Figure 3d), larger caliber airways with retained secretions (Figure 3e), a significant improvement in atelectatic areas and no evidence of pulmonary embolus (Figure 3f). The patient has been followed for two years with no signs or symptoms of pulmonary embolus.

**Discussion**

With increasing use of CT and CTPA, physicians will be confronted with more indeterminate scans. These suboptimal studies may lead to invasive procedures or unnecessary empiric treatment. Among the causes of suboptimal images with CT and CTPA are:

1. Beam hardening, especially in obese patients with airway collapse.
2. Motion artifact, especially in dyspneic patients with poor breath holding or transmitted cardiac pulsations.
3. Poor contrast enhancement of pulmonary vessels.
4. Volume averaging of enhancing vessels with adjacent atelectasis or lymphadenopathy.
5. Inadequate breath-holding for inspiratory and expiratory views.

Inspiratory and expiratory CT scans are useful diagnostically; however, some patients are unable to perform adequate breath holding and true inspiratory images are not possible. Our cases illustrate how the simple application
Figure 2: Use of noninvasive positive pressure ventilation to improve the quality of conventional CT and CTPA.
of CPAP can resolve some uncertainties with CT and CTPA. To our knowledge, the use of non-invasive CPAP to optimize imaging in adults has not been reported. A similar technique using controlled ventilation for sedated infants has been reported to improve image quality mainly by reduction of motion artifact. Our experience extends these observations to adults and demonstrates improvement in large airway imaging and optimization of vascular imaging.

Large airway disease may be difficult to rule out with simple CT and atelectasis may obscure the pulmonary parenchyma and vasculature. The application of CPAP appears to result in much better inspiratory images. CPAP stents open airways and identifies tracheomalacia and airway collapse thereby obviating the need for bronchoscopy. CPAP can also improve aeration of atelectatic areas and seems to improve angiographic resolution perhaps by optimizing lung expansion. Higher quality CTPA imaging of the pulmonary vasculature will reduce the risks of inappropriate anti-coagulation for suspected pulmonary embolism. Although not all patients will be able to tolerate the application of CPAP, we have found it to be a useful adjunct for improving the diagnostic accuracy of CT and CTPA.

Conflicts of interest

None of the authors have a conflict of interest to report.

References