What every radiologist should know about expiratory and in the prone position chest computed tomography

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Learning objectives

• To discuss the utility of the expiratory and prone chest computed tomography (CT).

• To review some pathologies in which these complementary studies can help make a more accurate diagnosis.
Background

Usually, chest computed tomography (CT) is performed with the patient in the supine position and at suspended full inspiration. However, it is sometimes necessary to perform further studies, such as a forced expiratory study or a CT in the prone position, for better evaluation of the lung parenchyma. The expiratory CT can reveal areas of air trapping, whereas prone studies allow evaluating dependent areas and cavitated lesions.
Findings and procedure details

Computed tomography scans in expiration and in the prone position are complementary studies to the inspiratory chest CT.

EXPIRATORY CT

On expiratory CT scans pathological areas are shown as hypodense zones consistent with air trapping, reflecting the airflow obstruction.

Expiratory CT studies may be useful in patients with diseases associated with airflow obstruction and can help distinguish between obstructive and infiltrative diseases in cases of inhomogeneous lung patterns on inspiratory CT.

TECHNIQUE

There are at least three techniques described to perform an expiratory CT: dynamic expiratory CT obtained during forced exhalation, spirometrically triggered expiratory CT and CT during suspended end expiration (this is the most widely used technique to visualize expiratory air trapping and the cases shown in this exhibit have been performed in this manner).

The acquisition of the CT can be sequential, performing a limited number of sections at different levels, or volumetric. This technique can be performed with low dose.

Regardless of the technique used, it is always advisable to explain and practice the expiratory manoeuvre with the patient before performing the scan.

FINDINGS ON A NORMAL EXPIRATORY CT (Fig. 1 on page 7)

In a normal expiratory CT scan lung density increases, decreasing air content in the lung. This increased density can be subjectively evaluated, but there are also been described objective methods of valuation as measurement using the Hounsfield units (HU).

Typically, dependent lung zones show a greater increase in density, which is even higher in the lower regions, having an anteroposterior density gradient that is significantly greater on expiratory scans than on inspiratory studies. The decrease in the air content also results in a decrease in lung volume.
There are as well changes in the airway, as the anterior bowing of the posterior tracheal membrane, useful to confirm that the expiratory technique has been successful.

**SEMILOGY OF AIR TRAPPING ON EXPIRATORY CT. AIR TRAPPING IN ASYMPTOMATIC PATIENTS**

On expiratory CT scans the areas of air trapping secondary to obstructive pathology may be focal, multifocal or diffuse, and they are shown as hypodense areas compared to the rest of the lung.

There is described a “normal air trapping” in asymptomatic subjects with normal functional respiratory tests that affects isolated secondary lobules and focal areas of lingula, middle lobe and upper segments of the lower lobes.

**EXPIRATORY CT FINDINGS IN SOME PULMONARY DISEASES**

Expiratory CT has been used to reveal air trapping in patients with airway diseases such as bronchiectasis (Fig. 2 on page 7), emphysema (Fig. 3 on page 8), sarcoidosis (Fig. 4 on page 9), hypersensitivity pneumonitis (Fig. 5 on page 10 and Fig. 6 on page 11), constrictive bronchiolitis of different etiologies (Fig. 7 on page 12 and Fig. 8 on page 13) included James Swyer syndrome (Fig. 9 on page 14), and asthma (Fig. 10 on page 15), revealing an obstructive pathophysiology.

There is also focal air trapping in other pathologies such as bronchial atresia, pulmonary sequestration (Fig. 11 on page 16) and focal infiltrative diseases of the airways, for example, tuberculosis (Fig. 12 on page 17).

Most of these diseases present alterations on the inspiratory CT scan, but in some cases such as in constrictive bronchiolitis, asthma, hypersensitivity pneumonitis and sarcoidosis, the basal study can not show abnormalities and pathology could be only demonstrated on the expiratory CT. For this reason, performing an expiratory CT on patients with normal inspiratory scan should be based on clinical suspicion (cases of Fig. 6 on page 11 and Fig. 8 on page 13).

Tracheobronchomalacia is a disease of the central airway with a weakness of the tracheal and bronchi walls due to softening of the cartilaginous structures of the airways. It is defined a 50% reduction in the lumen diameter of the trachea and main bronchi as criteria to diagnose tracheobronchomalacia and air trapping is often observed as well.
Performing a chest CT in the prone position is a useful tool that can confirm or rule out pathology in dependent areas. It allows differentiating between early interstitial lung disease and increased attenuation secondary to gravity dependant atelectasis, which can be very striking if the patient does not make a correct full inspiration (Fig. 13 on page 18, Fig. 14 on page 19, Fig. 15 on page 20 and Fig. 16 on page 21).

It may also be useful for the assessment of cavitated lesions that contain nodular lesions inside corresponding to mycetomas, because they are gravity dependent and should move with patient position (Fig. 17 on page 22).

The main problem of these additional scans (expiratory or prone CT) is the increase of radiation they entail, so its use should be addressed in selected cases, considering the basal inspiratory CT findings or the clinical suspicion, and always taking into account the possibility of conducting these studies with low-dose techniques.
**Fig. 1:** NORMAL FINDINGS ON EXPIRATORY CT SCAN

Inspiratory axial CT scan shows the normal round shape of the trachea (C). Expiratory axial CT scan shows the normal bowing forward of the posterior tracheal membrane (D, arrow). Note the normal homogeneous attenuation increase of the lung parenchyma with decreasing volume. The anteroposterior density gradient is also significantly greater on expiratory scans (A, B).

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Fig. 2: BRONCHIECTASIS 51 year-old woman, ex-smoker, with wheezing. Inspiratory CT showed cylindrical bronchiectasis and mosaic pattern of lung attenuation (A). Expiratory phase demonstrated the accentuation of the mosaic attenuation pattern and revealed air trapping areas (B).

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Fig. 3: EMPHYSEMA 60 year-old woman, ex-smoker, with COPD and severe obstructive pattern on spirometry who requires home oxygen therapy. A. Inspiratory CT: Homogeneous attenuation decrease of the lung parenchyma, consist with emphysema. B. Expiratory CT: Hypodense areas corresponding to air trapping zones.

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Fig. 4: SARCOIDOSIS 78 year-old woman with odynophagia and mediastinal widening on chest radiography caused by lymphadenopathies. Transbronchial biopsy of the lymphadenopathies was performed and it showed non-caseating granulomas, consistent with sarcoidosis. A. Mediastinal lymphadenopathies, which decreased in size after corticosteroid treatment. B. Inspiratory CT: Faint pattern of mosaic attenuation. C. Expiratory CT with MinIP reconstruction: Hypodense areas consistent with pathological zones of air trapping.

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**Fig. 5:** HYPERSENSITIVITY PNEUMONITIS 70 year-old man with parakeets at home who presented acute respiratory dyspnea. Chest radiography showed patchy interstitial condensations and revealed a faint interstitial pattern. Pulmonary criobiopsy was consistent with hypersensitivity pneumonitis. A. Inspiratory CT: Multiple areas of ground glass opacity and images of millimeter centrilobular nodules in the upper lobes. B. Expiratory CT: Three different lung densities are shown - ground glass opacity, normal lung density and abnormally hypodense areas reflecting air trapping.

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Fig. 6: HYPERSENSITIVITY PNEUMONITIS 48 year-old man working in a poultry slaughterhouse. He had progressive dyspnea with restrictive pattern and pulmonary function tests revealed decrease in diffusion lung capacity for CO. Pulmonary criobiopsy was consistent with hypersensitivity pneumonitis. A. Basal CT: Diffuse ground-glass opacity with poorly defined centrilobular nodules and radiolucent areas of lobular morphology. B. Control study in inspiration: No abnormalities. C. Expiratory control study: Small hypodense areas consistent with air trapping, with the largest area in the left lower lobe.

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Fig. 7: POST-TRANSPLANT BRONCHIOLOITIS OBLITERANS 30 year-old man with a history of acute lymphoblastic leukemia treated with hematopoietic progenitor cell transplantation and subsequent graft-vs-host disease. He had dyspnea related to constrictive bronchiolitis. A. The inspiratory study (A) showed faint patchy areas of ground glass density and a mosaic pattern of lung attenuation. B. The expiratory study emphasizes the mosaic pattern, indicating the presence of air trapping.

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Fig. 8: IDIOPATHIC BRONCHIOLITIS OBLITERANS 31-year-old male nonsmoker with exertional dyspnea, who presented severe obstruction without hyperreactivity on pulmonary function tests. The diagnosis was consistent with bronchiolitis obliterans. A. No significant alterations were observed in the inspiratory CT. B and C (MinIP reconstruction). The expiratory study showed areas of pathological air trapping, predominantly in the lower lobes, with a segmental distribution.

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**Fig. 9:** SWYER-JAMES (Post-infectious bronchiolitis obliterans) 45 year-old woman with dyspnea to mild efforts having obstructive pattern on pulmonary function tests. Inspiratory study (A, B, C) showed diffuse hypodensity of the left lower lobe with small proximal cylindrical bronchiectasis (arrow). On the expiratory study (D, E) significant air trapping of this lobe is identified. In the proximal airway obstructive lesions are not evident.

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Fig. 10: ASTHMA 77 year-old woman with diagnosed asthma. She had clinical worsening with dyspnea to small efforts and images consistent with bronchiectasis on chest X-ray. A. Inspiratory CT: Inhomogeneous pattern of the lung parenchyma with hypodense and hyperdense patchy areas of geographic borders. B. Expiratory CT: Pathological air trapping is confirmed.

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**Fig. 11:** PULMONARY SEQUESTRATION Incident finding of pulmonary sequestration on chest CT. In the dependent area of the left lower lobe, an area of soft tissue density with branched calcifications and hypodensity of the surrounding lung parenchyma is identified (B). It is confirmed as air trapping on expiratory study (C). The blood supply of the lesion is derived from the abdominal aorta (A), being consistent with pulmonary sequestration in relation to congenital anomaly. Venous drainage depends on branches of the left inferior pulmonary vein.

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Fig. 12: TUBERCULOSIS 58 year-old ex-smoker with dry cough and abnormal breath sounds on auscultation. He also presented dyspnea to great efforts. A, B. Soft tissue density surrounding the left hilum with thickening of the wall of proximal LUL and LLL bronchi and stenosis of them. Mediastinal and hilar lymphadenopathies. C. 2 cm partially cavitated nodule with irregular margins located in the left upper lobe. D. The expiratory CT with MinIP reconstruction showed air trapping of the left lower lobe secondary to lobar bronchus stenosis.

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Fig. 13: ARTIFACT Chest CT performed on a 54 year-old woman for evaluation of a nodule identified on preoperative chest radiography. In the lower lobes, predominantly in the dependent regions, areas of ground-glass attenuation are identified (A). The study was completed in the prone position (B), revealing disappearance of the areas of increased density, consistent with gravity dependant atelectasis. The occurrence of ground-glass opacities was also seen in the anterior regions (dependent regions in the prone position).

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Fig. 14: NSIP IN A PATIENT WITH SYSTEMIC SCLEROSIS 36 year-old woman with diffuse systemic sclerosis and pulmonary function tests within normal limits. Findings were consistent with nonspecific interstitial pneumonia (NSIP). Signs of nonspecific interstitial lung disease with ground-glass attenuation areas of subpleural predominance in the posterior regions of both lower lobes (A), which persist on prone scan (B). MIP reconstruction (C) showing the predominant involvement of the lower lung fields and subpleural regions. In the MinIP reconstruction (D) traction bronchiectasis (arrow) are shown, predominantly in the posterior regions of lower lobes.

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**Fig. 15:** NSIP IN A PATIENT WITH SCLERODERMA 59 year-old woman with scleroderma and mild effort dyspnea. On the basal CT increased basal density is observed, but the study was not performed at full inspiration and there were respiratory movements, so it was interpreted as an artifact. A subsequent study revealed that it was not an artifact, but corresponded to an extensive interstitial affectation, with traction bronchiectasis at present, with more evident changes in the middle lobe. In this case it could be earlier diagnosed if the initial study had been completed with an acquisition in the prone position. In cases of patients not able to follow breathing commands, the prone CT can help rule out pathology in dependent areas.

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Fig. 16: ASBESTOSIS 62 year-old male asbestos worker. Subpleural ground-glass opacities, predominantly in the lower lobes (A, C), which persist in the prone position (B, D). These findings can be seen in NSIP or, as in this case, in asbestosis in relation to his employment (is not possible to distinguish this disease from other pathology by this imaging technique). In addition calcified pleural plaques are identified in right paraspinal region and in the diaphragmatic pleura, characteristic of asbestos exposure by their morphology and distribution (arrows).

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Fig. 17: MYCETOMA 26 year-old female with a prior history of tuberculosis successfully treated at 18 years old, with residual right apical cavity and images of bronchiectasis. She had abundant and purulent broncorrea for three months and a radiography was performed showing increased density within the cavity, without air-fluid level. 6 cm cavity with irregular margins located in the right upper lobe with cystic bronchiectasis associated (A, C). The cavity had hypodense rounded content inside, which was mobilized in the prone position (B, D). Resection of the cavity with fungal content was performed.

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Conclusion

Every chest radiologist should know the utility of expiratory and prone studies, which can help to confirm or rule out some lung CT findings. These studies should be reserved for specific cases in which clinical or inspiratory CT make us suspect lung disease, as they involve a large increase in radiation.
References