Bronchopleural fistulas (BPF). Radiologic information from the beginning to the end.

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Purpose

The purpose of my presentation is to describe general characteristics of bronchopleural fistula, the radiological findings on multidetector CT (MDCT) and on chest plain radiograph, and the importance of image tests in this pathology.
Methods and Materials

We have reviewed the casuistry of our hospital about patients with bronchopleural fistula, with the corresponding surgical or bronchoscopic correlation and / or clinical and radiological follow-up as well as the literature on the topic.
Results

DEFINITIONS
A bronchopleural fistula (BPF) can be defined as the direct communication between the pleural space and a bronchus or as the persistent air-leak from a bronchus or from peripheral lung parenchyma towards the pleural space (1, 2). Distinction is needed between:
• Central BPF: communication between the pleural space and a central bronchus.
• Peripheral BPF: communication among the pleural space and a peripheral bronchus or the lung.

Central BPF:
• Cause: usually after surgical pulmonary resection, which was present in all our cases of central BPF (see figure 10, 11, 12, 13, 14, 15 and 16, 17 and 18), or after traumatism (2).
• This type of BPF is usually big and it needs surgical treatment (Qx).

Peripheral BPF:
• Cause: pulmonary infections (see figure 1, 2, 3, 4, 5, 6 and 7 and 8 and 9) usually necrotizing, penetrating or blunt trauma, barotrauma and malignancies (2).
• They are smaller and they respond to no surgical treatment (antibiotics, pleural drainage).
• Sometimes they are not visible in the bronchoscopy, for which the CT is very useful (See figure 3 and 8 and 9).

CAUSES
• Surgical pulmonary resection: it is the BPF's most common reason (5). To see detailed explanation hereinafter.
• Pulmonary necrotizing infections or empyemas. To see detailed explanation hereinafter.
• Others:
  • OTHER THORACIC TRAUMATISM: IATROGENICS CAUSES (thoracic tubes, biopsy, toracocentesis, nasogastric tube malpositioning, oleothorax, positive-pressure mechanical ventilation (3)), POST-TRAUMATIC NEUMATOCELES (2), BAROTAUMA (6).
  • BULLAE (2), PERIPHERAL BRONCHIECTASIS (2), COMPLICATED EMPHYSEMA (6).
  • PULMONARY INFARCTS: sterile / septic (see figure 8 and 9).
  • NEOPLASMS AND THEIR TREATMENT. Thoracic neoplasms can produce a BPF especially if the neoplasm has a pleural component (3). Chemotherapy and radiotherapy cause tissue necrosis, which induces BPF's formation. There are multiple factors which contribute to the pulmonary injury related to the radiation: antecedents of previous radiation, associated chemotherapy, extensive volumes of radiated lung parenchima,
high dose of radiation, shortening of the time of treatment and remove steroid treatment (7). They can appear like early or late complication of the radiotherapy.

O **OTHERS:** reumatoïd nodules.

**POST-INFECTIONOUS BPF (see figures 1, 2, 3, 4, 5, 6 and 7 y 8 and 9).**

- Microorganisms related to infections necrotizing or empyemas are:
  1. anaerobic microorganisms: frequently in alcoholic patients or other patients with risk of bronchoaspiration; symptoms are usually subacute.
  2. gram negatives
  3. pyogenic infections
  4. tuberculosis: BPF can develop during the active or during the chronic phase, years later, like complication of pleuritis (see figure 8 and 9).
  5. fungi (less frequent)

- **Pathophysiology:** BPF is originated in empyemas in phase of organization (see figures 1, 2, 3, 4, 5 and 6). Phases of an empyema: it starts as sterile pleural exudated (exudative phase), adjacent to an infectious pulmonary consolidation; without antibiotics treatment, the microorganisms invade pleural liquid, which will attract polymorphonuclears, other leukocytes and fibrin (fibrinopurulent phase); there is trend to loculation in this phase. Fibroblasts grow in visceral and parietal pleura later (phase of organization). The fibrotic response may be so exuberant that a rind develops around the underlying lung, encasing it. The pleural liquid can drain spontaneously across the thoracic wall, which causes an empyema necessitatis, or inside the lung, which causes a BPF.

**POST-SURGICAL BPF (see figures 10, 11, 12, 13, 14, 15 and 16, 17 and 18).**

- Incidence: 2.5-3%, though according to surgical series, the percentage of BPF has change from 0.8 to 15 % (4); the percentage of incidence varies depending on the author: from 2-13 % (7) to 1.5-28 % (5); the more extensive is the resection, the larger is the incidence of BPF (5).
- It is one of the most serious and dangerous complications after the pneumonectomy: it has high morbidity, mortality (25-71 %) and it increase the hospital stay. Pronostic is worse than BPF not related with previous surgery (5).
- Incidence is major in patients with previous right pneumonectomy and right lower lobe lobectomy (5), antecedent present in all our surgical patients (see figure 10, 11, 12, 15 and 16, 17 and 18,) except in one (see figure 13 and 14); surgery on the right main bronchus or on the intermediary bronchus has more risk than surgery on the lobar bronchi (5). A clear reason does not exist for this trend.
- They usually appear 2 weeks after the surgery.
- There are factors that cause ischemia on pulmonary parenchima, and favor the BPF formation, as:
  - Infections (they are usually associated to BPF): BPF are frequent after pulmonary infections like tuberculosis.
  - Association with chemotherapy and radiotherapy.
  - Pre-surgical risk factors (5) to take into account: fever, use of steroids, H. influenzae in sputum, high erythrocyte sedimentation rate and anemia.
  - Surgical and postsurgical risk factors (4): extensive peribronquial resection, big bronchial stump, previous radiotherapy, previous toracotomy, haematoma in the line of
suture, longwearing mechanical ventilation post-pneumonectomy, stump on right main or intermediary bronchus, association with inflammatory disease and residual tumor in the margins of the stump. As recommendation, it seems that manual suture (or a combination of manual and mechanic suture) has less risk of later FBP than mechanical isolated suture (5).

o Signs and symptoms on postsurgical period (4): fever, hemoptysis, cough, brown sputum, liquid or blood expectoration, fetid breath, subcutaneous emphysema, persistent air-leak in drainage tubes. However, all these signs and symptoms are unspecific. According to Misthos, the better test to detect a post-surgical BPF is chest radiography, sometimes superior to bronchoscopy. Signs on chest radiography are described hereinafter.

• Pathophysiology related with radiological findings: normal evolution after pneumonectomy is a progressive collapse of the space post-pneumonectomy, with initial reabsorption of gas and posterior reabsorption of liquid, which confirms an ascendant gas-fluid level because of changes on the air-fluid proportion. The obliteration of the space takes place between 3 weeks and 7 months after pneumonectomy. If the gas-fluid level gets down instead of ascending, we must suspect entrance of air and / or exit of liquid from pleural space across the tracheobronchial tree by formation of a BPF; this causes mediastinic displacement towards the not surgical side (5) and, in occasions, formation of consolidations in the contralateral lung corresponding to the aspirated pleural liquid. This circumstance must be distinguished from benign reasons of decrease of the pleural liquid, where the contralateral mediastinic displacement will not happen (5) and from other reasons of increase or presence of gas in the pleural space: gas-forming bacteria or iatrogenic causes.

• Occult broncheopleural fistula (OBPF) or microfistula: sometimes a small bronchial dehiscence is not confirmed by habitual technologies of diagnosis (bronchoscopy, nuclear medicine, etc), even when signs and / or symptoms of suspicion should persist. It’s necessary to point out that early bronchoscopy after surgery is not sensitive for the detection of a BPF, being more reliable radiological findings (4). This type of BPF is known as occult broncheopleural fistula (OBPF) o microfistula. Its incidence is not clear; in Misthos’s study it was 3.3 %. Its pathophysiology consists of a valvular mechanism that makes that tracheal air goes towards pleural space but not inversely (4); this explains that they scarcely should have neither cough nor aspiration to the contralateral lung. When they are not corrected, its size increases and the valvular mechanism gets lost, having more clinical manifestations at the time. When radiological findings suggest an OBPF, a follow-up is needed very closely (practically daily) with chest radiographs.

• Technologies for the confirmation: bronchoscopy, air-leak after to take out the tube of thoracostomy; ventilation gammagraphy with Xe 133 or other gases (they will remain trapped in the pleural space).

RADIOLOGICAL FINDINGS:
A. CHEST RADIOGRAPH:
It is the gold standard to detect post-surgical BPF according some authors (4).

SIGNS:
• In general: hydropneumothorax: air-fluid level of different dimensions in orthogonal planes (posteroanterior and lateral) (3) (see figures 1, 4, 13 and 15 and 16); this allows to distinguish a hydropneumothorax from an abscess that contains air, which will show an air-fluid level of similar dimensions in all its orthogonal planes. It is necessary to consider other causes of hydropneumothorax different from a BPF (see section " differential diagnosis ").
• In addition, in patients with previous pneumonectomy, associate signs are:
  - loss of normal mediastinic displacement towards surgical hemithorax and displacement towards contralateral hemithorax (see figure 13) or not contraction of the post-pneumonectomy space. The normal evolution towards the progressive collapse of the space of pneumonectomy will appears as mediastinic displacement towards the surgical hemithorax and ascent of the hemidiaphragm ipsilateral; sometimes, just the fact of persistence of air in pleural space without changes over time, is indicative of BPF’s presence, being the failure in shrinkage of the space of pneumonectomy an independent indicative sign of development of a FBP (p=0.03) (4) (see figure 15 and 16). Likewise, increase of the transverse diameter of postpneumonectomy space must make suspect the existence of a BPF, even in presence of ascent of the hemidiaphragma ipsilateral.
  - sudden increase of air in space of pneumonectomy (or in the adjacent thoracic wall).
  - decrease of liquid in space of pneumonectomy. This finding together with the previous one will appear as a descent of air-fluid level.
  - sometimes, opacities on contralateral lung appear due to aspiration of liquid from pneumonectomy space (see figure 15 and 16).

PAPER OF CHEST RADIOGRAPH:
• To suggest the presence of a possible BPF
• Monitoring of therapy

B. MDCT:
• It visualizes the BPF in 30-50 % of the cases, but this information has been obtained from a study in which the majority of cases were studied by means of routine CT with thick slices (only 21 % of cases were studied with thin slices (1.5-1 mm)) (2).
• The assessment of thin slices and the administration of intravenous (iv) contrast are useful to demonstrate a peripheral BPF (see figures 6 and 7). The administration of iv contrast helps to distinguish the limit between lung and pleura in necrotizing pneumonia.

SIGNS:
• Hydropneumothorax, frequently formed by appearance of gas in a previous pleural effusion (see figure 2, 3 and 5). BPF’s classic sign is that of a pneumothorax that does not resolve after placing tube of pleural drainage. Nevertheless, if we have a pneumothorax that doesn’t resolve with a pleural tube, it is necessary to consider other possibilities besides the BPF (see section " differential diagnosis ").
• Communication between the central or peripheral bronchus and the pleura or between the lung and the pleura can be visualized, which must be studied with lung window (see all the figures, except 1, 4 and 13).
• Signs in parenchyma-pleura fistula: focal areas of consolidation of low density that communicate directly with a pleural effusion with characteristic of empyema, and an obvious disruption of the visceral pleura (3, 8). Not always air is going to be visualized in the pleural space. (3).
• In patients with previous pneumonectomy, sometimes consolidations appear in contralateral lung due to aspiration of liquid from pneumonectomy space (see figure 15 and 16 and 18).

PAPER OF MDCT:
With MDCT, we are able to know:
• Number of BPF (sometimes there is more than one).
• Size.
• Location:
•
  o Periferic BPF are usually placed in areas of chronic inflammation, which causes bronchiectasis or bronchiolectasis (3).
  o Parenchyma-pleura fistulas are usually formed in aggressive pulmonary neoplasm or severe infections, as necrotizing pneumonia.
  o Post-surgical fistulas are usually proximal, with a major trend in surgeries of main right and intermediary bronchus.

• Etiology: both postsurgical BPF and BPF related with bullae are more difficult to demonstrate than BPF of another cause (1). According to Ricci's work, the MDCT identifies seldom parenchyma-pleura fistulas caused by bullae (the BPF was not visualized in 92 % and surgery was needed in 58 %), having probably a low sensitive for this type of BPF even when they are of great size. It also happens when BPF is related to emphysema (2). Excluding BPF of those origins, a trend was verified to the surgical management in those cases of peripheral BPF visible in MDCT (surgery in 70 % of cases), which suggests that these BPF are bigger than the no visible ones.

• Important information for the attitude, being a guide for other diagnostic procedures and / or interventions (bronchoscopy, thoracocentesis, pleural drainage, guided fine-needle aspiration or biopsies), as well as to decide the medical, surgical or endoscopic management. Besides the previous information, with MDCT we can also study the relation of the BPF with the margins of resection (3). Treatment of the peripheral FBP is controversial, but the MDCT is a tool that provides very useful information, in cases in which, depending on clinical course, can be needed a surgical management (2). According to conclusions of an experts' panel for the treatment of pneumothorax (American College of Chest Physicians expert panel), in cases of spontaneous pneumothorax, MDCT was a useful tool for the management of air leak or for surgical planning.

C. DIFFERENTIAL DIAGNOSIS:
Air appearance in the pleural space is not always indicative of BPF, and we have to consider other possibilities:
• Recent pneumonectomy
• Pleural infection or thoracic wall infection for gas-forming organisms
• Iatrogenic introduction of gas in the pleural space (thoracocentesis …)

Despite the previous possibilities, persistence of pleural effusion or hydropneumothorax in spite of tube of drainage pleural not always indicates BPF, being other causes:

- Non-functioning or misplacement of the tube. It is also valuable with MDCT.
- Malignant pleural effusion: a big pleural effusion that is not modified after a thoracocentesis can indicate malignant effusion, in the appropriate clinical context: tumor implants in visceral pleura prevent reexpansion of the lung ("trapped" lung).
- Chronic empyema with severe affection of visceral pleura: it traps the lung and prevents its reexpansion; in these cases, pleural affectation is not solved in spite of the good placement of the pleural tube of drainage.

**TREATMENT (4,5):**

As for the treatment, there is no an established consensus. The possibilities are:

- Conservative treatment: medical treatment and drainage of the postpneumonectomy space, which protects from consequences of the contralateral mediastinic displacement and from aspiration to the contralateral lung.
- Surgery or placement of a STENT: closing of the BPF with a vascularized graft, in early BPF; in late BPF, trans-sternal trans-pericardic repair or thoracotomy with coverage of the BPF with muscle or another tissue (see figure 18).
- Endoscopic treatment: sometimes carried out before surgery, awaiting the recovery of the patient or, in some circumstances, it is the only available treatment. The endoscopic treatment has a better result in small and peripheral BPF, being capable neither those BPF bigger than 8 mm nor big and central BPF, which will need surgery or implantation of a STENT (5). This anatomic information can be provided by the MDCT.

Criteria that influence the surgical decision are: recurrence of pneumothorax, duration of air-leak and initial response to the conservative treatment. MDCT helps to the therapeutic decision, and, according some authors (2), if a BPF is visible in the MDCT, generally it will need surgical treatment.

There have been described classifications of the types of BPF destined to facilitate decision-making for the treatment, classifying patients in postsurgical or not and, in turn, in subgroups being established according to the etiology of the BPF. In general, a previous surgery (generally related with neoplasm or pulmonary necrosis) has a major incidence of BPF and it implies a worse prognosis. To see the above mentioned classification, I would recommend the reader reference 5.
FIGURE 1. Alcoholic patient with cough and difficulty in breathing. Chest x-ray with projection PA (A) and lateral (B). Air-fluid level in the right hemithorax of different dimensions in PA and lateral projections, indicative of an extrapulmonary lesion: hydropneumothorax (black arrows). Bronchiectasis and probable cavities in LSD (black circle). Loss of volume of both LLSS (main bronchi displaced towards cranial -blue arrows-, trachea displaced to the right - green arrow- by a more important loss of volume of LSD- and ascent of left hilium-white arrow-) and irregular opacities in the upper half of left pulmonary field (white circle), probably corresponding to fibrotic tissue. The findings suggest right BPF, probably secondary to tuberculosis or necrotizing pneumonia.
Fig. 2: FIGURE 2. The same case of FIGURE 1. Chest CT with intravenous (IV), contrast and thin reconstructions in axial (A, C and D) and coronal planes (B). Cavity of thin wall in LSD (white asterisk) which communicates (black arrow), with the pleural space (blue asterisk) and hydropneumothorax ipsilateral (red arrow), findings indicative of a BPF. Varicose (green arrows) and cystic (blue arrow) bronchiectasis in LLSS and severe architectural distortion in LSD. Bronchoscopy and mycobiologic study :right chronic empyema; positivity for Str. Anginosus (Anaerobic) , with BPF of 1 cm, by where material suggestive of caseum flows; tuberculosis has not been confirmed in the current moment; extensive destructuring pulmonary, with bronchiectasis.

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**Fig. 3:** See the caption inside the slide.
**Fig. 4:** See the caption inside the slide.

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**Fig. 5:** See the caption inside the slide.

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**FIGURE 5**

Chest CT with iv contrast; reconstruction sagittal in MPR (B) (27/02/09); right hydropneumothorax (white asterisk); consolidation in LID (black asterisk) where we can observe a communication between peripheral lung and pleural cavity (white arrows); enhancement pleural and hypertrophy of extrapleural fat (black arrow), indicative of exudate of chronic evolution. Pleural effusion was present in a CT a year before (D). BPF was confirmed by bronchoscopy; *Candida albicans*, *Enterobacter cloacaе*, *Klebsiella pneumoniae* and *Streptococcus pneumoniae* were positive in the pleural liquid, and *Streptococcus Aureus* in the transbronchial sample. Increase of the air pleural in successive control (see E and F).
FIG. 6: FIGURE 6. Postinfectious BPF. Patient with constitutional syndrome and dyspnea. Initial chest x-ray (A): thin wall cystic lesion (multiloculated single or multiple lesions in the left lung (asterisks)), emphysema in LLSS, visible in CT (B) and consolidation in the apical segment of the RIL, visible in CT (square in A, C and E). At axial plane it is doubtful if there is a single or several cystic lesions (asterisks), some with air-fluid level (blue arrows), and it is not clear if their location is intrapulmonary (superinfected bullae or intrapulmonary abscesses) or extrapulmonary (hydropneumothorax). The obtuse angle formed by the collection and the interface lung - thoracic wall (yellow arrows), the split pleura sign (black arrows; very suggestive of empyema) and well defined edges of the adjacent lung (red arrows) are signs that suggest a more probably pleural location. In thin MPR reconstructions with lung window (G-I) we can see that small pleural collections are communicated among them, so it is an extensive pleural affectation. There is a peripheral BPF (white arrow in G), with an adjacent consolidation (circle in I), that is the cause of the pneumothorax, which improves but is not solved by a tube of pleural drainage (green arrow in L). Pyopneumothorax was microbiologically confirmed, with positive culture for Citrobacter braakii (enterobacteria). BPF was not confirmed with other tests.
Fig. 7: Continuation of FIGURE 6. Postinfectious BPF. Patient with constitutional syndrome and dyspnea. Initial chest x-ray (A): thin wall cystic lesion (multiloculated single or multiple lesions in the left lung (asterisks)), emphysema in LLSS, visible in CT (B) and consolidation in the apical segment of the RIL, visible in CT (square in A, C and E). At axial plane it is doubtful if there is a single or several cystic lesions (asterisks), some with air-fluid level (blue arrows), and it is not clear if their location is intrapulmonary (superinfected bullae or intrapulmonary abscesses) or extrapulmonary (hydropneumothorax). The obtuse angle formed by the collection and the interface lung - thoracic wall (yellow arrows), the split pleura sign (black arrows; very suggestive of empyema) and well defined edges of the adjacent lung (red arrows) are signs that suggest a more probably pleural location. In thin MPR reconstructions with lung window (G-I) we can see that small pleural collections are comunicated among them, so it is an extensive pleural affectation. There is a peripheral BPF (white arrow in G), with an adjacent consolidation (circle in I), that is the cause of the pneumothorax, which improves but is not solved by a tube of pleural drainage (green arrow in L). Pyopneumothorax was microbiologically confirmed, with positive culture for Citrobacter braakii (enterobacteria). BPF was not confirmed with other tests.

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**Fig. 8:** FIGURE 8. BPF associated with infection and pulmonary embolism. Successive x-ray and CT coronal reconstructions (C, H and J) and MinIP reconstructions in sagittal and axial planes (D and G). Patient with tuberculosis with left empyema and left BPF, both of them confirmed. Left hydropneumothorax (white asterisk) not solved after tube of pleural drainage adequately placed (arrow), which suggests a BPF; we can see the possible communication between a peripheral bronchus and pleura (white arrows) and an adjacent consolidation (blue square). There is fibrotic lesions, architectural distortion and bronchiectasis (BE) in LLSS with air trapping (yellow asterisk) in lingula; cystic lesion (blue asterisk) of thin wall in LSD (cystic BE or bulla). Centroacinar nodules suggestives of reactivation of tuberculosis (circle). Pulmonary embolism in left interlobar artery (blue arrow). Pleural cavity and embolism was reduced in the posterior control (I and J). The microorganism in the empyema was not specified. M. tuberculosis, Pseudomonas aeruginosa and H. Influenzae were positive at sputum. BPF can have been caused by active tuberculosis or by pulmonary embolism.

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Fig. 9: Continuation of FIGURE 8. BPF associated with infection and pulmonary embolism. Successive x-ray and CT coronal reconstructions (C, H and J) and MinIP reconstructions in sagittal and axial planes (D and G). Patient with tuberculosis with left empyema and left BPF, both of them confirmed. Left hydropneumothorax (white asterisk) not solved after tube of pleural drainage adequately placed (arrow), which suggests a BPF; we can see the possible communication between a peripheral bronchus and pleura (white arrows) and an adjacent consolidation (blue square). There is fibrotic lesions, architectural distortion and bronchiectasis (BE) in LLSS with air trapping (yellow asterisk) in lingula; cystic lesion (blue asterisk) of thin wall in LSD (cystic BE or bulla). Centroacinar nodules suggestives of reactivation of tuberculosis (circle). Pulmonary embolism in left interlobar artery (blue arrow). Pleural cavity and embolism was reduced in the posterior control (I and J). The microorganism in the empyema was not specified. M. tuberculosis, Pseudomonas aeruginosa and H. Influenzae were positive at sputum. BPF can have been caused by active tuberculosis or by pulmonary embolism.
**Fig. 10:** See the caption inside the slide.

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Fig. 11

Same patient of FIGURE 8. Comparing with the previous CT after surgery (C), it exists a major component of air in the right hydro pneumothorax (the air-fluid level places more down in a more caudal cut (black arrows)). Pneumopericardium is detectable in the postsurgical CT, because of recent surgery (white arrow).

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CT 21/10/09: Angiography CT of pulmonary arteries (contiguous cuts from A to D): possible communication (white arrow) between intermediary bronchus (black arrow) and adjacent right paramediastinic cavity of hydropneumothorax (asterisk). A pulmonary embolism existed in the artery for RIL (not showed). Bronchoscopy did not visualize the BPF. The patient improved without surgery, so confirmation does not exist.

**Fig. 12:** See the caption inside the slide.

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**Fig. 13:** See the caption inside the slide.

Post-surgical AP x-ray (pneumonectomy on 18/11/08) (A), successive PA x-ray (B) and PA and lateral x-ray 51 days later (C-D): postsurgical left hydropneumothorax with initial normal evolution of the post-pneumonectomy cavity towards the collapse (* in A-B) and posterior increase of gas and liquid (air-fluid level in C and D-arrow, formed when the patient is in bipedestation) and contralateral medistinic displacement.

Presurgical CT (E): broncogenic carcinoma of LSI (†) that involves the main left bronchus.
**FIGURE 14.** Post surgical BPF.

Same patient of FIGURE 11. Left hydropneumothorax (blue arrow) with contralateral mediastinic displacement; communication between left main bronchus and pleural cavity (arrow), confirmed by bronchoscopy (“stump of left pneumonectomy with fistulous orifice to 2 cm of carina”).

**Fig. 14:** See the caption inside the slide.

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Fig. 15: See the caption inside the slide.

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**Fig. 16:** Continuation of FIGURE 15. See caption inside the slide.
**Fig. 17:** See caption inside the slide.

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Fig. 18: See caption inside the slide.

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Conclusion

Chest x-ray and MDCT have a fundamental role in this pathology. The information provided by MDCT is especially useful for the detection of a BPF, determination of the cause, characterization, to assist in the decision-making process for diagnosis and/or treatment and follow-up. We must be familiar with the radiological findings and know factors related to BPF, to be able to suspect and to look for this type of pathology, and to give relevant information to the clinician for the management of the patient.
References


