

RAPID COMMUNICATION

Anaplastic lymphoma kinase gene rearrangement in non-small-cell lung cancer in a Brazilian population

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INTRODUCTION

Lung cancer is the leading cause of cancer deaths worldwide (1). Non-small-cell lung carcinoma (NSCLC), which represents approximately 80% of all lung cancer cases, is frequently diagnosed at advanced stages of the disease and is associated with short survival time. Although the prognosis of this disease remains poor, significant advances in the genetics and treatment of NSCLC have been made in recent years.

In 2007, Soda et al. (2) identified the transforming *EML4-ALK* fusion gene in 6.7% of NSCLC patients. This fusion transcript, which presents potent oncogenic activity both *in vitro* and *in vivo* (2,3), is formed by the translocation of the echinoderm microtubule-associated protein-like 4 (*EML4*) gene (2p21) and anaplastic lymphoma kinase (*ALK*) gene (2p23). Subsequent studies have shown that between two and eight percent of all NSCLC cases may harbor *ALK* rearrangements, which are almost always mutually exclusive with *EGFR* and *KRAS* mutations. Moreover, these patients are frequently younger, non- or light smokers and have adenocarcinomas (2,4-23). Recently, crizotinib, an orally available small-molecule inhibitor of the *ALK* tyrosine kinase, was approved for the treatment of *ALK*-rearranged NSCLC patients, with successful results (24-29). The two most widely used methods for the diagnosis of *ALK*-rearranged NSCLC are fluorescence *in situ* hybridization (FISH) and immunohistochemistry.

Because there is no information about the prevalence and clinical characteristics of *ALK*-rearranged NSCLC in Latin America in the literature, the aim of this study was to evaluate NSCLC with *ALK* rearrangement in Brazilian patients.

MATERIALS AND METHODS

Case Selection

This study included 62 consecutive NSCLC cases received from August 2010 to September 2011 for *ALK* rearrangement testing using FISH (30) by Consultoria em Patologia, a large Anatomic Pathology and Molecular Pathology reference laboratory located in Botucatu, São Paulo State, Brazil.

Tissues from small biopsies and lung resection specimens were used. The ages and genders of the patients were registered.

Fluorescence *in situ* hybridization (FISH)

FISH was performed on formalin-fixed, paraffin-embedded tumor samples using a probe specific to the *ALK* locus (Vysis LSI *ALK* dual color, break apart rearrangement probe; Abbott Molecular, Des Plaines, IL, USA) according to the manufacturer's instructions. The FISH results were analyzed under a fluorescence microscope (Zeiss Axio Imager M1, Carl Zeiss AG, Oberkochen, Germany) with the appropriate filters (Chroma Technology GmbH, Fuerstenfeldbruck, Germany) and Metafer 4 software (MetaSystems, Altlußheim, Germany). FISH-positive cases were defined as those in which more than 15% of the cells (at least 40 neoplastic cells were counted) presented with split orange and green signals or an isolated orange signal, as previously described (31,32).

Immunohistochemistry

For comparison with FISH results, *ALK* protein expression was determined by immunohistochemistry using the mouse monoclonal antibody 5A4 (code ab17127, ABCAM, Cambridge, MA, USA), which was found to show high concordance with *ALK* gene status, as determined by molecular tests (13,14,23,33-36). Briefly, 3- μ m-thick unstained histologic sections of lung carcinoma tissue were used in all cases. The sections were deparaffinized in xylene and rehydrated in a graded series of alcohol in phosphate-buffered saline. The sections then were submitted to antigen retrieval in a microwave. Subsequently, slides were incubated overnight with the 5A4 antibody at a pre-standardized concentration (1:200), washed with phosphate-buffered saline, and incubated with Novocastra Novolink Polymer Detection System (Leica Biosystems Newcastle Ltd., Newcastle upon Tyne, UK). Diaminobenzidine was used as the chromogen, and sections were counterstained with hematoxylin and coverslipped. A case was considered positive for *ALK* if $\geq 10\%$ of the tumor cells showed intense cytoplasmic immunostaining.

RESULTS

Of the 62 NSCLC cases included in this study, two (3.2%) showed *ALK* rearrangement by FISH: one case presented an isolated orange signal along with one fusion signal in tumor cells, and the other showed split orange and green signals along with one fusion signal. These two FISH-positive cases were also positive for *ALK* by immunohistochemistry, with

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No potential conflict of interest was reported.

strong cytoplasmic immunostaining in virtually all tumor cells. All of the other sixty FISH-negative cases were also negative for *ALK* using immunohistochemistry.

Both of the patients with FISH- and *ALK* immunohistochemistry-positive NSCLC were men (36 years old and 45 years old; mean: 40 years). One of them had no history of tobacco smoking, and the other was a light smoker who had stopped smoking some months prior to the diagnosis. The group of patients (n=60) presenting *ALK*-negative tumors by FISH varied in age from 32 to 87 years (mean: 58 years; median: 59 years), and most of these patients were male (33 patients).

According to the new international multidisciplinary classification of lung adenocarcinomas proposed by the International Association for the Study of Lung Cancer, the American Thoracic Society and the European Respiratory Society (37), tumors from the two patients with *ALK*-positive FISH were classified as invasive adenocarcinoma, acinar predominant. One tumor had papillary areas, and the other was rich in mucinous areas. The 36-year-old patient with invasive adenocarcinoma, acinar predominant with papillary areas, was also tested for *EGFR* and *KRAS* mutations; the tumor was negative for both mutations. Figure 1 presents the morphologic characteristics of the two *ALK*-positive cases, including FISH and immunohistochemical findings.

DISCUSSION

Clinical characteristics associated with *ALK* rearrangement in NSCLC include adenocarcinoma histology, younger age at diagnosis, and non- or light smoker status, similar to those described for *EGFR* mutations. The prevalence of NSCLCs with *ALK* fusion varies from 2% to 8% in the literature, and most studies have been conducted in Asian countries or in the United States of America. Table 1 presents the frequency of *ALK*-rearranged NSCLC in several countries. In Japan, the prevalence of lung cancer with *ALK* rearrangement varied widely, from 2.4% to 6.7% (2,16,19). In Korea, the frequency of *ALK*-positive NSCLC ranged from 3.7% to 4.2% (11,13,14). In China, it was approximately 5% (4,12,15). In the USA, the prevalence varied from 5.6 to 8.2%

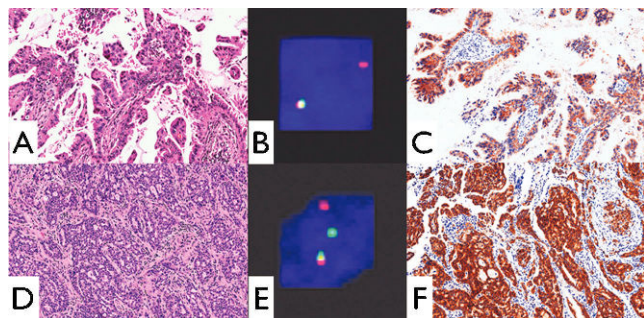


Figure 1 - *ALK*-rearranged NSCLCs. A. Invasive adenocarcinoma, acinar predominant with papillary areas, in a 36-year-old male patient (case 1). B. FISH of case 1 showing one isolated orange signal along with one fusion signal (positive for *ALK* rearrangement). C. *ALK* expression in case 1: diffuse and intense cytoplasmic immunostaining. D. Invasive adenocarcinoma, acinar predominant with mucinous areas, in a 45-year-old male patient (case 2). E. FISH of case 2 showing split orange and green signals along with one fusion signal (positive for *ALK* rearrangement). F. *ALK* expression in case 2: intense cytoplasmic immunostaining in virtually all tumor cells.

Table 1 - Prevalence of *ALK*-rearranged NSCLC in different countries.

Authors, year of publication	Country	<i>ALK</i> -rearranged tumors
Soda et al., 2007 (2)	Japan	6.7% (n=75)
Rodig et al., 2009 (17)	USA	5.6% (n=358)
Wong et al., 2009 (4)	China	4.9% (n=266)
Sakairi et al., 2010 (19)	Japan	6.4% (n=109)
Takahashi et al., 2010 (16)	Japan	2.4% (n=211)
Sun et al., 2010 (15)	China	5.7% (n=52)
Paik et al., 2011 (11)	Korea	3.8% (n=735)
Li et al., 2011 (12)	China	5% (n=202)
Kim et al., 2011 (13)	Korea	3.7% (n=449)
Paik et al., 2011 (14)	Korea	4.2% (n=453)
Yang et al., 2012 (23)	USA	8.2% (n=300)
Lopes et al. (present study)	Brazil	3.2% (n=62)

(17,23). These findings show that ethnicity likely does not strongly influence the prevalence of *ALK*-rearranged lung carcinomas, which is in contrast to *EGFR*- and *KRAS*-mutated tumors (38-41).

To the best of our knowledge, however, no information about the prevalence and clinical characteristics of these tumors in Latin America, including Brazil, is available in the literature.

In the present study, 3.2% (2 out of 62) of NSCLC cases in Brazilian patients were *ALK* fusion positive by FISH. These two male patients were younger than those with *ALK*-negative FISH, had a history of no or light smoking, and their tumors presented invasive adenocarcinoma histology similar to that described in the literature. Both tumors were histologically classified as acinar predominant: one tumor had papillary areas, and the other was rich in mucinous areas.

Consistent with the results of other studies (13,14,23,33-35), a high concordance between FISH and immunohistochemistry results for the detection of *ALK*-positive NSCLCs was found in the present study. Although FISH remains the gold standard technique for the diagnosis of *ALK*-rearranged lung carcinoma, immunohistochemistry may play an important role in the determination of *ALK* status in NSCLC in the near future. Because data regarding the role of immunohistochemistry in the detection of *ALK*-positive lung cancer are limited in the literature, additional studies are necessary.

The use of crizotinib has changed the history of NSCLC treatment, with dramatic results in patients with *ALK*-rearranged tumors. A recent phase I/II clinical trial showed that 47 of 82 (57%) patients with *ALK* fusion-positive lung tumors confirmed by FISH had objective responses to crizotinib, and an additional 27 (33%) patients displayed stable disease (9). These data highlight that the diagnosis of *ALK*-rearranged NSCLC is crucial.

As previously stated, the present study is the first in Latin America to present clinicopathologic information regarding *ALK*-rearranged NSCLC in patients from this geographic area. Further studies are encouraged to expand our knowledge on *ALK*-positive NSCLC in Latin America and Brazil.

AUTHOR CONTRIBUTIONS

Bacchi CE was responsible for designing and supervising the project, and writing and revising the manuscript. Lopes LF was responsible for data collection, data analysis, and writing the manuscript. All authors approved the final version of the manuscript.

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