Lung Cancer

Chemotherapy-Associated Pulmonary Toxicity—Case Series from a Single Center

Tilak TVSVGK1, Ajay Handa2, Kishore Kumar3, Deepti Mutreja4, Shankar Subramanian1

1Department of Internal Medicine, Armed Forces Medical College (AFMC), Pune, Maharashtra, India
2Department of Medicine, INHS Asvini, Mumbai, Maharashtra, India
3Department Medicine, Command Hospital Air Force (CHAF), Bangalore, Karnataka, India
4Department of Pathology, Armed Forces Medical College (AFMC), Pune, Maharashtra, India


Abstract

Background  Pulmonary toxicity due to chemotherapeutic agents can occur with many established and new drugs. Strong clinical suspicion is important as the clinical presentation is usually with nonspecific symptoms like cough, dyspnea, fever, and pulmonary infiltrates. Timely discontinuation of the offending agent alone can improve the condition.

Methods  A prospective observational study on patients receiving chemotherapy at an 800-bedded tertiary care hospital was performed from 2014 to 2016. Consecutive patients on chemotherapy, presenting with nonresolving respiratory symptoms were evaluated with contrast-enhanced computerized tomography of chest, diffusion lung capacity for carbon monoxide (DLCO), fiberoptic bronchoscopy with lavage, and biopsy, after excluding all causes for pulmonary infections. Descriptive data has been depicted.

Results  A total of 18 patients were evaluated for persistent symptoms of dry cough, dyspnea, and fever among 624 who received chemotherapy during the study period. Ground-glass opacities on high-resolution CT was the most common imaging finding, others being patchy subpleural consolidation and pleural effusion. Lymphocyte-predominant bronchoalveolar lavage was detected in nine. Eight of the 15 patients who underwent DLCO, had abnormal results. Seven had significant histopathological findings on bronchoscopic lung biopsy, which revealed organizing pneumonia as the most common pattern. Paclitaxel, fluorouracil, gemcitabine, and tyrosine kinase inhibitors were the common culprit drugs. Discontinuation alone of the culprit drug was effective in 15 and 3 needed oral corticosteroids for relief of symptoms. None of the patients died due to the toxicity.

Conclusion  An incidence of 2.8% for chemotherapy-induced lung injury was seen in our observational study of 3 years, with parenchymal, interstitial, and pleural involvement due to various chemotherapeutic agents. Oral steroids maybe required in a subset of patients not responding to discontinuation of the culprit agent.

Keywords

► chemotherapy-associated pulmonary toxicity
► ground-glass opacities
► transbronchial lung biopsy
► organizing pneumonia


© 2021, Medintel Services Pvt Ltd. This is an open access article published by Thieme under the terms of the Creative Commons Attribution-NonDerivative-NonCommercial-License, permitting copying and reproduction so long as the original work is given appropriate credit. Contents may not be used for commercial purposes, or adapted, remixed, transformed or built upon. (https://creativecommons.org/licenses/by-nc-nd/4.0/). Thieme Medical and Scientific Publishers Private Ltd A-12, Second Floor, Sector -2, NOIDA -213001, India
Introduction
Chemotherapy-associated pulmonary toxicity is increasingly being recognized as a complication of therapy. The incidence of this toxicity varies from 0.1 to 15% in various studies. Older drugs as well as novel antineoplastic agents are known to involve lungs in various ways. The clinical manifestations of this entity range from dry cough to sputum production, dyspnea, fever, chest pain, hypoxemia, and respiratory failure. The clinical presentation resembles any pneumonia and hence it needs exclusion in every suspected case. Evaluation of a case likely to have antineoplastic agent-related lung injury requires detailed evaluation of the drug list, markers for drug reaction like eosinophilia and transaminitis, and imaging in the form of high-resolution computerized tomography (HRCT) or contrast-enhanced CT (CECT) scan of the chest. Further evaluation involves study of diffusion lung capacity of lung for carbon monoxide (DLCO), fiberoptic bronchoscopy (FOB) with bronchoalveolar lavage (BAL) and transbronchial lung biopsy (TBLB). The radiological findings are often not very clear on routine chest skiagram. CT scan patterns of involvement include patchy or diffuse ground-glass opacities, reticular or reticulonodular opacities, consolidation areas, or nodules. Common findings on BAL include hypercellularity with neutrophilia or lymphocytosis. The biopsy of lung shows findings of cellular interstitial pneumonitis, eosinophilic inflammatory infiltrates, vasculitis, and organizing pneumonia patterns.

The mainstay of therapy includes discontinuation of the culprit drug and use of corticosteroids for varying duration, guided by clinical response. Alternative agents are usually employed to treat the primary condition. Prompt recognition of this potentially reversible condition is important to prevent disabling morbidity and mortality.

An observational study to detect pulmonary involvement due to chemotherapeutic agents was conducted at a tertiary teaching hospital in South India.

Patients and Methods
The study was an observational study on patients receiving chemotherapy. The study was conducted at an 800-bedded tertiary teaching hospital with a Malignant Diseases Treatment Centre. The duration of the study was from January 2014 to December 2016. All patients receiving chemotherapy were included in the study and were observed for new-onset respiratory symptoms. They were evaluated to exclude underlying old lung disease, infection, and progression of malignancy. After exclusion of these causes, they were considered to have chemotherapy-induced lung toxicity and treated for the same.

We included consecutive patients on chemotherapy-induced pulmonary toxicity from our center into the study. All patients underwent thorough history and physical examination followed by hemogram and complete biochemical profile. The patients with clinical suspicion of chemotherapy-induced lung toxicity underwent further evaluation with chest radiograph, HRCT or CECT chest, spirometry, DLCO, FOB, BAL fluid examination, and TBLB.

Inclusion Criteria
1. Patients of malignancy on chemotherapy or targeted therapy.
2. Development of new-onset respiratory symptoms while on chemotherapy or targeted therapy lasting > 48 hours.

Exclusion Criteria
1. Patients with preexisting lung disease.
2. Presence of active infection or malignant process involving the lungs.

New-onset respiratory symptoms were defined as cough, dyspnea, or wheeze, which has not responded to symptomatic therapy or persists despite symptomatic therapy for 48 hours. Infective cause and progression of malignancy as a cause for these symptoms was excluded in all cases.

All suspected patients underwent chest radiographs and HRCT of chest (64-slice scanner) and spirometry, and diffusion capacity for carbon monoxide was tested in all cases. Those with abnormal HRCT chest underwent flexible bronchoscopy performed by a pulmonologist. The morphology of bronchial tree was documented. BAL was obtained using 100 mL of sterile normal saline. BAL fluid was sent for malignant cytology, differential cytology, Gram stain, fungal stain, acid-fast bacillus stain, and cultures for aerobic bacteria and fungi. TBLB was performed in appropriate cases and sample sent for histopathological examination.

The suspected culprit drug was immediately withheld upon suspecting the diagnosis. Those not responding to cessation of the drug therapy were exhibited oral corticosteroids. Patients were started on alternative drugs for treatment of the cancer, once they recovered and became symptom free.

Results
Patients and Materials
A total of 624 patients received chemotherapy or targeted therapy during the study period. Sixty-four patients were noted to have new-onset respiratory symptoms requiring further evaluation or therapy after excluding infection. Eighteen patients had abnormal HRCT chest and underwent further evaluation. Seven patients had demonstrable abnormalities on bronchoscopic lung biopsy.

Eight patients of carcinoma breast on adjuvant therapy and four patients of metastatic carcinoma gall bladder were receiving chemotherapy with weekly paclitaxel. Two patients of metastatic squamous cell carcinoma lung were receiving gemcitabine and one patient of metastatic adenocarcinoma lung was on gefitinib as targeted therapy for epidermal growth factor receptor mutation positivity. One patient of metastatic carcinoma rectum was on 5-flourouracil (5-FU) with leucovorin and oxaliplatin. Two patients of chronic myeloid leukemia (CML) were on dasatinib as a second-line agent.
The most common symptom was with dry cough, which was not responsive to cough suppressants. Other symptoms included dyspnea on exertion, wheezing, and fever.

All patients underwent routine hemogram and biochemistry including acute phase reactants to exclude active infection precipitating the symptoms. None of the patients had any sign of infection.

Radiology
Chest X-ray was abnormal in two patients with reticulonodular opacities in lower zones bilaterally. HRCT chest was abnormal in all patients. The common findings included areas of ground-glass opacities, patchy subpleural areas of consolidation suggestive of organizing pneumonia (Fig. 1), and bilateral pleural effusion (one case of CML on dasatinib).

Fiberoptic Bronchoscopy
All patients underwent FOB with BAL and TBLB under topical anesthesia with 2% lignocaine with monitoring of oxygen saturation and pulse oximetry in the bronchoscopy suite. The patients were given supplemental oxygen by face mask if oxygen saturation was less than 90% breathing room air. Postprocedure, all patients underwent chest radiograph after 2 hours to look for pneumothorax postlung biopsy. The bronchoscopy showed normal appearance of tracheobronchial mucosa in all the cases. There was hypoxemia in 7 cases during bronchoscopy, which improved with oxygen supplementation during the procedure and resolved in 1 hour post-procedure in all cases.

Diffusion Lung Capacity of Carbon Monoxide
Spirometry was normal in 3 cases and showed mild restrictive defect in 15 cases. DLCO was tested in 15 cases and showed diffusion impairment in 8 cases, which was mild to moderate (range, 76–54% predicted).

Bronchoalveolar Lavage
All patients underwent BAL fluid examination for differential cytology. BAL was normal in 9 cases and abnormal in 9 cases, and lymphocytic predominant BAL fluid was the most common pattern. BAL for malignant cytology was negative in all cases. Infective workup and cultures were negative in all cases (details of cytological findings as depicted in Table 1).

Transbronchial Lung Biopsy
All 18 patients underwent TBLB. The biopsy revealed normal lung tissue in 9 cases, nonspecific chronic alveolar interstitial inflammation in 2 cases, and organizing pneumonia pattern in 5 cases; biopsy yielded inadequate tissue in 2 cases (Fig. 2). There were no cases with pneumothorax post-TBLB in this series (details of pathological findings as depicted in Table 1).

Management and Outcome
The offending drug was discontinued in all patients. Initial management included use of bronchodilators and cough suppressants. Oral corticosteroids were used for three patients (gefitinib, 5-FU, and dasatinib) for 4 to 8 weeks due to persisting symptoms after drug withdrawal. There was significant improvement in the symptoms with the management. The patients recovered over a period of 4 weeks. None of the patients were challenged with the culprit drug. Alternate therapies were started for these patients. None of the patients died due to the adverse effect of the culprit drug.

Discussion
A variety of chemotherapeutic agents can cause histopathologic patterns of lung injury. The incidence of chemotherapy-induced infiltrative pneumonitis is not uncommon but the diagnosis is difficult due to the nonspecific clinical and radiological presentations.15

![Fig. 1 High-resolution computerized tomography (HRCT) chest shows patchy areas of ground-glass opacities (GGOs) in both lower lobes and few areas of subpleural GGO and nodular lesions (suggestive of organizing pneumonia pattern).](file)

![Fig. 2 Hematoxylin and eosin (H&E), 100× photomicrograph of transbronchial lung biopsy showing areas of normal alveoli (black arrow) and pathologic areas showing patchy filling of alveoli by loose connective tissue plugs (red arrows) suggestive of organizing pneumonia.](file)
Leukemia – Lymphoma and Myeloma

for only 0.7% of all AML cases. According to a large study of acute myeloid leukemia (AML).

The MS can arise before the diagnosis of intramedullary AML without evidence of an underlying primary, or nonleukemic MS. The isolated MS is a rare disease with an incidence of 2 in 1,000,000 adults, accounting for 746 patients in a national dataset, isolated MS may develop as a consequence of leukaemia.

In 1811, myeloid sarcoma (MS) was described for the first time by Burns. Afterward, in 1853, King called the disease chloroma due to its greenish appearance. MS, also known as myeloid sarcoma, is a rare but significant form of extramedullary myeloid sarcoma.

According to the World Health Organization, MS is categorized as a subtype of acute nonlymphoblastic leukemia (ANLL) which is associated with the presence of acute myeloid leukemia (AML) and the lack of B lineage.

This is an open access article published by Thieme under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Table 1 Details of patients with chemotherapy-associated pulmonary toxicity

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Age</th>
<th>Gender</th>
<th>Diagnosis</th>
<th>Drug used(route)</th>
<th>Schedule/Dose/Duration</th>
<th>Symptoms</th>
<th>Imaging</th>
<th>BAL</th>
<th>Lung biopsy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>65</td>
<td>M</td>
<td>Metastatic squamous cell carcinoma lung</td>
<td>Gemcitabine (IV)</td>
<td>D1 and D8 q 3-weekly / 1000 mg / 3 months (3 cycles)</td>
<td>Dyspnea</td>
<td>Organizing pneumonia</td>
<td>Lymphocyte predominant</td>
<td>Organizing pneumonia</td>
</tr>
<tr>
<td>2.</td>
<td>56</td>
<td>M</td>
<td>Metastatic carcinoma gall bladder</td>
<td>Paclitaxel (IV)</td>
<td>D1, D8, D15 q 4-weekly / 150 mg / 6 months (6 cycles)</td>
<td>Dyspnea</td>
<td>GGO</td>
<td>Lymphocyte predominant</td>
<td>Organizing pneumonia</td>
</tr>
<tr>
<td>3.</td>
<td>62</td>
<td>M</td>
<td>Chronic myeloid leukemia</td>
<td>Dasatinib (PO)</td>
<td>Daily / 70 mg twice a day / 3 years</td>
<td>Fever Cough Dyspnea</td>
<td>Pneumonia with bilateral pleural effusion</td>
<td>Lymphocyte predominant</td>
<td>Organizing pneumonia</td>
</tr>
<tr>
<td>4.</td>
<td>51</td>
<td>F</td>
<td>Carcinoma breast</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 130 mg / 10 weeks</td>
<td>Dry cough</td>
<td>GGO</td>
<td>Lymphocytes predominant</td>
<td>Non-specific interstitial inflammation</td>
</tr>
<tr>
<td>5.</td>
<td>52</td>
<td>M</td>
<td>Metastatic adenocarcinoma lung</td>
<td>Gefitinib (PO)</td>
<td>Daily / 150 mg / 09 months</td>
<td>Fever</td>
<td>Dyspnea</td>
<td>Dry cough</td>
<td>GGO</td>
</tr>
<tr>
<td>6.</td>
<td>54</td>
<td>M</td>
<td>Metastatic carcinoma rectum</td>
<td>5-Flourouracil (IV)</td>
<td>2-weekly / 600 mg (bolus) and 1000 mg (22 h CIVI) / 3 months (06 cycles)</td>
<td>Fever</td>
<td>Dyspnea</td>
<td>Dry cough</td>
<td>Patchy areas of consolidation</td>
</tr>
<tr>
<td>7.</td>
<td>52</td>
<td>F</td>
<td>Carcinoma breast</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 11 weeks</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>GGO</td>
<td>Lymphocyte predominant</td>
</tr>
<tr>
<td>8.</td>
<td>68</td>
<td>M</td>
<td>Metastatic squamous cell carcinoma lung</td>
<td>Gemcitabine (IV)</td>
<td>D1 and D8 q 3-weekly / 1000 mg / 3 months (4 cycles)</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>Subpleural consolidation</td>
<td>Normal</td>
</tr>
<tr>
<td>9.</td>
<td>56</td>
<td>M</td>
<td>Metastatic carcinoma gall bladder</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 10 weeks</td>
<td>Fever</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>GGO</td>
</tr>
<tr>
<td>10.</td>
<td>42</td>
<td>F</td>
<td>Carcinoma breast</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 10 weeks</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>GGO</td>
<td>Lymphocyte predominant</td>
</tr>
<tr>
<td>11.</td>
<td>54</td>
<td>F</td>
<td>Carcinoma breast</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 09 weeks</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>Patchy alveolar opacities</td>
<td>Normal</td>
</tr>
<tr>
<td>12.</td>
<td>52</td>
<td>F</td>
<td>Carcinoma breast</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 12 weeks</td>
<td>Fever</td>
<td>Dry cough</td>
<td>GGO</td>
<td>Normal</td>
</tr>
<tr>
<td>13.</td>
<td>44</td>
<td>F</td>
<td>Chronic myeloid leukemia</td>
<td>Dasatinib (PO)</td>
<td>Daily / 70 mg twice a day / 6 months</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>Bilateral pleural effusion</td>
<td>Normal</td>
</tr>
<tr>
<td>14.</td>
<td>42</td>
<td>F</td>
<td>Carcinoma breast</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 09 weeks</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>Patchy alveolar opacities</td>
<td>Normal</td>
</tr>
<tr>
<td>15.</td>
<td>45</td>
<td>M</td>
<td>Metastatic carcinoma gall bladder</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 10 weeks</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>Patchy areas of consolidation</td>
<td>Normal</td>
</tr>
<tr>
<td>16.</td>
<td>48</td>
<td>F</td>
<td>Metastatic carcinoma gall bladder</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 08 weeks</td>
<td>Fever</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>GGO</td>
</tr>
<tr>
<td>17.</td>
<td>39</td>
<td>F</td>
<td>Carcinoma breast</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 10 weeks</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>Bilateral Centrilobular nodules</td>
<td>Normal</td>
</tr>
<tr>
<td>18.</td>
<td>57</td>
<td>F</td>
<td>Carcinoma breast</td>
<td>Paclitaxel (IV)</td>
<td>Weekly / 120 mg / 09 weeks</td>
<td>Dry cough</td>
<td>Dyspnea</td>
<td>Patchy consolidation</td>
<td>Normal</td>
</tr>
</tbody>
</table>

Abbreviations: BAL, bronchoalveolar lavage; CIVI, continuous IV infusion; GGO, ground-glass opacities; IV, intravenous; PO, per oral.
We describe 18 cases of chemotherapy-induced lung toxicity at a single center. All these cases were thoroughly evaluated including lung biopsy to establish the possible pathology. All of them responded to discontinuation of the drug except three who required oral corticosteroids for 4 to 8 weeks. As is true with most cases of drug-induced lung disease, the diagnosis of chemotherapy-induced lung disease can be difficult to confirm. The acute or insidious onset and timing of clinical manifestations associated with chemotherapy-induced lung toxicity is quite variable. It may present during the initial cycle of treatment, after subsequent cycles, or even years later as is the case with carmustine-associated pulmonary fibrosis. A single chemotherapy agent may be associated with different lung injury patterns.

Fifteen patients had toxicity due to chemotherapeutic agents while three had tyrosine kinase inhibitors as the culprit drug. Paclitaxel was responsible for lung injury in majority of the cases. The average time of onset of respiratory symptoms in these patients ranged from 8 to 11 weeks of therapy. Symptoms due to paclitaxel can develop from hours to weeks after its administration. Delayed hypersensitivity is the most likely cause of symptoms in patients who present later during therapy. The radiological abnormalities in these patients included organizing pneumonia in two and one had nonspecific interstitial pneumonia. Contrary to our cases, it is rare for hypersensitivity reactions due to paclitaxel to manifest on HRCT scans.

Dyspnea is one of the most common symptoms in patients with chemotherapy-induced lung injury. Nearly all of our patients had dry cough and dyspnea as the presenting symptoms. Fever was present in six of the patients and no focus of infection was found on complete evaluation. 5-FU and gemcitabine are known to be associated with lung injury and with increased chances of mortality. Our patients on fluorouracil or gemcitabine responded to discontinuation including lung biopsy to establish the possible pathology. Major of cases respond to discontinuation of culprit drug with some needing short course of steroids. Pharmacogenomic studies in future may predict the subset of patients who may develop chemotherapeutic agent–induced lung injury.

Conflict of Interest
None declared.

References

In 1811, myeloid sarcoma (MS) was described for the first time by Burns. Afterward, in 1853, King called the disease chloroma due to its greenish appearance. MS, also known as granulocytic sarcoma, is an extramedullary tumor composed of mature or immature myeloid blast cells. According to the World Health Organization, it frequently involves skin, orbit, bone, periosteum, lymph nodes, and gastrointestinal tract, soft tissue, central nervous system, and testis. Because of its different locations of presentation, MS is a real diagnostic challenge particularly in patients without initial bone marrow involvement. The correct diagnosis and symptoms, and the lack of diagnostic algorithm, MS is a real diagnostic challenge. It may precede, present concurrently or follow acute myeloid leukemia (AML) in de novo case or may also be present and might be the only manifestation of recurrent AML, myelodysplastic syndrome, or chronic myeloid leukemia. MS can arise before bone marrow involvement. The diagnosis of intramedullary AML without evidence of leukemia, primary, or nonleukemic MS. The isolated MS is a rare disease with an incidence of 2 in 1,000,000 adults, accounting for only 0.7% of all AML cases. According to a large study of acute myeloid leukemia (AML), the MS can arise before the diagnosis of AML. The MS is a subtype of AML, and it is classified within the M6 category of AML. The presence of MS is associated with a worse outcome. Since the MS can occur in any site, and it can present as a mass, it is necessary to be aware of its clinical presentation and differential diagnosis. In the spinal region, the MS is extremely rare. Here, we report three cases of MS derived from spine presenting with back pain, paraplegia, paraparesis, respectively, and review the relevant literature.

Case 1
An 84-year-old female was admitted to our hospital with a 3-month history of back pain radiating to left buttock and left thigh. The patient had no known history of cancer. On physical examination, the patient had a 5 cm mass on the left buttock. Laboratory tests revealed mild-to-moderate anemia, leukocytosis, and raised erythrocyte sedimentation rate (ESR). Imaging studies of the thorax, abdomen, and pelvis showed presence of ill-defined lytic lesion with sclerosis involving bone and soft tissue. Biopsy of lesion revealed MS on immunohistochemistry. Bone marrow was normocellular with a very mild bulging with firm consistency. Blood reports revealed that mild-to-moderate tenderness on sacral region was present. The patient was afebrile. The patient was anorexic and had weight loss of about 5 kg. Physical examinations including complete blood count, renal function test, and liver function test were normal.

Case 2
A 47-year-old male presented with back pain radiating to left side. There was no history of bone pain. On physical examination, there was a 10 cm mass on the left side of L4 to S5 vertebrae involving adjacent paraspinal muscles. Blood reports revealed mild-to-moderate anemia, leukocytosis, and elevated ESR. Imaging studies showed a well-defined lytic lesion with sclerosis involving bone and soft tissue. Biopsy of lesion revealed MS on immunohistochemistry. Bone marrow was normocellular. The patient was afebrile.

Case 3
A 52-year-old female presented with back pain for 2 months. On physical examination, there was a 5 cm mass on the left buttock. Laboratory tests revealed mild-to-moderate anemia, leukocytosis, and elevated ESR. Imaging studies showed a well-defined lytic lesion with sclerosis involving bone and soft tissue. Biopsy of lesion revealed MS on immunohistochemistry. Bone marrow was normocellular. The patient was afebrile. The patient was anorexic and had weight loss of about 5 kg. Physical examinations including complete blood count, renal function test, and liver function test were normal.

The correct diagnosis and symptoms, and the lack of diagnostic algorithm, MS is a real diagnostic challenge. It may precede, present concurrently or follow acute myeloid leukemia (AML) in de novo case or may also be present and might be the only manifestation of recurrent AML, myelodysplastic syndrome, or chronic myeloid leukemia.