Adult Burkitt Lymphoma: Advances in Diagnosis and Treatment

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Burkitt lymphoma (BL) is a unique B-cell lymphoma characterized by a high proliferation rate and cytogenetic changes related to c-myc proto-oncogene overexpression. Burkitt lymphoma is a highly aggressive B-cell lymphoma that is most frequently seen in children and young adults in endemic areas.

ABSTRACT: Burkitt lymphoma is a unique B-cell malignancy with a high proliferation rate and characteristic genetic changes involving the c-myc oncogene. Burkitt lymphoma is common in children but also occurs in adults, where distinction from diffuse large B-cell lymphoma may pose a problem. The development of brief, very intensive chemotherapy regimens has led to a very high cure rate in children with Burkitt lymphoma. The use of these regimens in adults, often in combination with the antibody rituximab (Rituxan), has also made the cure of a majority of adults possible. Burkitt lymphoma in adults cannot be treated effectively with the common regimens used for diffuse large B-cell lymphoma such as CHOP-R (cyclophosphamide, doxorubicin HCl, vincristine [Oncovin], prednisone, rituximab). Prompt diagnosis and initiation of appropriate therapy with attention to the possibility of tumor lysis syndrome are necessary for optimal results.

Burkitt lymphoma (BL) is a unique B-cell lymphoma characterized by a high proliferation rate and cytogenetic changes related to c-myc proto-oncogene overexpression. Burkitt lymphoma is a highly aggressive B-cell lymphoma that is most frequently seen in children and young adults in endemic areas. As a result of the worldwide epidemic of acquired immunodeficiency syndrome (AIDS), the number of cases of adult BL has increased substantially in the past 3 decades. TABLE 1

### Distinction Between Burkitt Lymphoma and Diffuse B-Cell Lymphoma

The challenge of correctly distinguishing BL in an individual patient becomes particularly critical when the clinician is confronted with a treatment decision. Burkitt lymphoma is rapidly fatal if not treated appropriately with brief intensive chemotherapy, which has yielded an excellent result. However, when patients with BL are treated with regimens for diffuse large B-cell lymphoma (DLBCL), the outcome is usually poor.[1-4] On the other hand, brief intensive therapy is not the favored choice for DLBCL since it is associated with significant adverse effects (Table 1). Therefore, use of more advanced modalities to establish an accurate diagnosis is crucial, to avoid undertreatment or overtreatment of patients. The aim of this review is to discuss adult BL and emphasize controversial topics in diagnosis and treatment.

### Historical Background and Epidemiology

Burkitt lymphoma was first described by Dr. Dennis Burkitt, an Irish surgeon who was working for the Colonial Medical Service in Uganda. He noted a high incidence of rapid-growing tumors affecting the jaws of African children in the endemic areas of malaria. At that time, Dr. Burkitt described the tumor...
as a form of sarcoma.[5] Three years later, the tumor was recognized histologically as a malignant lymphoma by Burkitt and O’Conor when they studied a series of cases—involving extranodal sites in African children—that shared the geographic distribution, histologic features, and high incidence of jaw involvement.[6]

Burkitt lymphoma accounts for over half of all childhood cancers in endemic areas, and 40% to 50% of childhood non-Hodgkin lymphomas (NHLs) in nonendemic areas (America and Western Europe).[7] BL is a rare lymphoma in adults, except in human immunodeficiency virus (HIV)-positive patients. It constitutes 1% to 2% of all non-HIV adult lymphomas in Western Europe and the United States.[8]

### TABLE 2

**Burkitt Lymphoma Variants**

The World Health Organization (WHO) classified BL on the basis of geographic distribution and clinical presentation into three subtypes: endemic, sporadic, and immunodeficiency-associated BL (Table 2). These subtypes share the same morphologic and immunohistologic features.

**Endemic BL**

The endemic variant is the prototype and the most common form. It describes cases that have been observed in children in equatorial Africa and Papua New Guinea, with a geographic distribution pattern that corresponds with endemic falciparum malaria. The highest risk of BL is seen between 10° north and south of the equator.[9] The disease has a tendency to occur in low, warm, and humid lands,[10] and it is an important health issue in areas such as the Middle East, North Africa, and parts of South America. It is characterized by a high incidence of jaw and other facial bone involvement. Central nervous system (CNS) and bone marrow involvement in children has been reported in 12% and 22% of cases, respectively.[11] Nearly all endemic cases are associated with EBV infection.[12]

**Sporadic BL**

In contrast, the sporadic form describes cases that occur outside the endemic distribution of the disease and is seen in industrialized nations such as North America and Europe. It accounts for a minor percentage of adult lymphomas, and its peak incidence occurs in the second and third decades.

Sporadic BL is a highly aggressive disease with a propensity to invade bone marrow and CNS, with a reported incidence of 30% to 38% and 13% to 17% of cases, respectively.[13] Lymph node involvement is more common among adults than children.[14] Whereas the jaw is the most common affected site in the endemic form, it is infrequently involved in sporadic Burkitt.[15] The abdomen is the most common site in sporadic cases, particularly the terminal ileum, cecum, and intra-abdominal lymph nodes. However, it also occurs in sites such as the ovary, kidney, pancreas, liver, omentum, Waldeyer’s ring, and breast.[16] Breast involvement is observed almost exclusively in girls at the onset of puberty and in lactating women.[17] One-third of patients have B symptoms at presentation (unexplained fever higher than 38°C (100.4°F) in the prior month, unexplained weight loss greater than 10% in the past 6 months, and recurrent drenching night sweats in the prior month). Patient with abdominal disease usually present with abdominal mass or pain, bowel obstruction, gastrointestinal bleeding, or a syndrome mimicking appendicitis. In the sporadic form, 15% to 30% neoplastic cells are EBV-positive.[18]

**Immunodeficiency-Associated BL**

### TABLE 3
St. Jude/Murphy Staging System for Burkitt Lymphoma

The third group is immunodeficiency-associated BL which is seen in HIV-positive patients, to a lesser extent in posttransplant recipients,[19,20] and in some individuals with congenital immunodeficiency.[21] Burkitt lymphoma occurs over a thousand times more often in HIV-positive individuals than in the general population.[22] It accounts for 30% to 40% of all HIV-associated NHLs.[23] Compared to other AIDS-associated NHLs, BL occurs in younger patients with higher CD4 counts. Since the introduction of highly active antiretroviral therapy (HAART), the prognosis of HIV-associated NHL has improved significantly with standard chemotherapy protocols, except for BL, which continues to carry an unsatisfied prognosis with current chemotherapy.[24] The majority of patients are diagnosed with stage III or IV disease (Table 3).[25] Relapse with CNS involvement tends to occur early in the course of the disease.[26] Posttransplant BL tends to occur after a relatively long interval following the transplant (average interval was 4.5 years in one series).[19]

Pathology and Pathobiology

TABLE 4

Pathologic Variants of Burkitt Lymphoma

Histologically, classic BL is characterized by a uniform proliferation of medium-sized cells with round nuclei, stippled chromatin, and multiple small, membrane-associated nucleoli (Table 4). The cells have a moderate amount of basophilic cytoplasm, with numerous lipid vacuoles in smears and touch preparations. The hallmark of BL is the presence of a “starry sky” appearance seen at low-power magnification. This appearance is created by numerous macrophages containing ingested fragments of tumor cells as a consequence of rapid proliferation and a high rate of apoptosis (Figure 1). The rate of cell division is extremely high, as reflected by the presence of numerous mitotic figures and a high fraction of proliferating cells (> 95%) as demonstrated by Ki-67 stains. This classic form of BL is seen in most endemic cases and in most sporadic pediatric cases.[2] FIGURE 1
Morphologic Features of Burkitt Lymphoma

The WHO classification has identified Burkitt lymphoma and leukemia as a single entity of mature B-cell lymphoma with two related morphologic variants in addition to the classic form: BL with plasmacytoid differentiation and atypical BL/Burkitt-like lymphoma. These variants share the genetic and immunophenotypic features of classic BL, but they have atypical morphologic features.[27] Atypical Burkitt lymphoma (ABL) has morphologic features intermediate between BL and DLBCL,[3] with greater pleomorphism in nuclear size and shape, cells with more prominent central nucleoli, and the presence of large centroblasts admixed, and it is seen more frequently in sporadic adult cases (Figure 1). The revised European-American lymphoma (REAL) classification gave ABL a provisional status,[28] which was a confusing entity for clinicians, who often found it difficult to choose between treating the disease as BL or as DLBCL. The Southwest Oncology Group reported that ABL is an entity of high-grade lymphoma much closer to BL than DLBCL, which can be differentiated by its characteristic phenotypic and molecular features, and a higher proliferation index than is usually seen in DLBCL.[29] The WHO classification resolved this dilemma by recognizing ABL as a morphologic variant of BL that requires intensive therapy.

BL with plasmacytoid differentiation is seen frequently in AIDS patients. It is distinguished by features of ABL and the presence of monotypic cytoplasmic immunoglobulin.

The features of BL are consistent with a germinal center-cell stage of differentiation, based on the presence of somatically mutated immunoglobulin heavy chain variable-region genes and the expression of characteristic GC B-cell surface markers such as CD10 and Bcl-6.[30-32] Some cases of endemic BL show evidence of ongoing somatic hypermutation, which supports its germinal center-cell origin.[33]

Immunophenotypic Features

The cells of BL typically express monotypic surface IgM, CD19, CD20, CD22, CD10, Bcl-6, and CD79a, and are negative for CD5, CD23, Bcl-2, and nuclear terminal deoxynucleotidyl transferase.
(TdT). Lack of surface immunoglobulin has been reported in a few cases. The presence of CD10 and Bcl-6 expression supports the germinal center-cell stage of differentiation. A remarkable feature of BL is the high growth fraction (> 95%) as demonstrated by Ki-67. The leukemic cells of BL express a mature immunophenotype that distinguishes it from precursor B-cell acute lymphoblastic leukemia (ALL).

Atypical BL demonstrates more phenotypic diversity and may exhibit a lower proliferation rate compared to the classic form and more frequent expression of Bcl-2. On the other hand, some cases of DLBCL exhibit an overlapping immunophenotype with BL including a high proliferation rate, which makes the distinction of ABL from DLBCL difficult based on immunophenotypic characteristics alone. Expression of CD21—the EBV receptor—is seen in EBV-positive cases. It is present in the vast majority of endemic cases of BL.

**Molecular Genetics**

**TABLE 5**

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<th>Treatment of Burkitt Lymphoma</th>
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| C-myc encodes a transcriptional factor. It has a marked influence on cell proliferation, growth, cellular differentiation, and apoptosis. Dysregulation of the gene is the key element in BL pathogenesis at the molecular level. Translocation of the c-myc oncogene is universal in BL. This abnormality juxtaposes the c-myc oncogene location at 8q24 and one of three immunoglobulin loci. The most common translocation is (8;14), which is seen in 80% of BL cases; it occurs between the c-myc oncogene and Ig heavy chain gene (IgH). About 15% of BL cases have a t(2;8) rearrangement, where the translocation occurs between c-myc and kappa light chain gene, and the remaining 5% have an (8;22) translocation between c-myc and lambda light chain gene. The detection of translocations is not always feasible by performing a routine cytogenetic assessment. Fluorescence in situ hybridization (FISH) using a break-apart probe or long-segment polymerase chain reaction increases the chance of identifying the presence of these translocations. The position of the breakpoint in relation to c-myc gene at chromosome 8 and IgH at chromosome 14 is not variable. Studies have found a correlation between the site of the breakpoint and the geographic distribution of BL. In the endemic form, the breakpoint on chromosome 8 tends to occur upstream of the c-myc gene, while the breakpoint in the IgH locus is usually located within the joining segment. In sporadic as well as AIDS-associated cases, the translocation breakpoint often falls within the c-myc gene on chromosome 8 and in the IgH switch region in chromosome 14. This may imply a diverse pathogenesis for the variants of BL, which may explain the clinical variations between the endemic and sporadic subtypes.

Making BL diagnosis more challenging, c-myc was found to be sometimes overexpressed in DLBCL, as 5% to 15% of DLBCL cases harbor this rearrangement. Considering that 40% of NHLs are DLBCL and 10% of these cases involve c-myc translocation, in contrast to BL, which constitutes 2% of NHLs with all cases having the translocation, the majority of NHLs with c-myc translocations are not BL. Some reported cases of ABL also lacked the c-myc translocation. Both (8;14)(q24;q32) and (14;18)(q32;q11) translocations can occur in the same malignant cells. Tumors harboring this combination have more aggressive disease, present in more advanced stages, and have a worse prognosis. The t(14;18) causes overexpression of Bcl-2, which promote cell survival through apoptosis inhibition. Dual translocation has been reported in BL cases, especially ABL, but also DLBCL. More complex cases of BL with triple translocations have been reported, and this has also been linked to poor prognosis. The management...
approach in such complex translocation cases is not well defined. Whether “double-hit” DLBCL responds better to intensive therapy or CHOP-R (cyclophosphamide, doxorubicin HCl, vincristine [Oncovin], prednisone, rituximab [Rituxan]) is a question that has not yet been answered. The pathogenesis of BL is not exclusively explained by c-myc dysregulation; other genetic aberrancies have been found to occur frequently. A p53 mutation was observed in 30% to 40% of BL cases in two reports,[57,58] and the 6q deletion was detected in 30% of cases in another study.[59]

**Gene Profile Studies**

Differentiating BL from DLBCL can be extremely difficult in some cases, but the distinction has important therapeutic implications. Gene-expression profiling was introduced in the past few years to compare gene expression based on the differential expression of thousands of genes measured simultaneously. Recent studies conducted by Dave et al[47] and Hummel et al[48] reported a more reliable approach in subclassification of mature aggressive B-cell lymphoma by gene-expression profiling using DNA microarrays. These studies found that 17%[47] and 34%[48] of cases identified as having the Burkitt gene-expression profile had previously been classified as DLBCL or unclassifiable high-grade lymphoma by expert hematolpathologists, based on WHO criteria. On the contrary, 0.5% to 4% of the cases that had been called BL or ABL lacked the genetic signature of BL, which implies that these cases could represent DLBCL or a high-grade lymphoma rather than BL. Both studies revealed an occasional absence of the c-myc rearrangement in some cases. These studies proved the superiority of using gene signature in BL diagnosis over WHO criteria, although this is not easily applied in the clinic because of the complexities of the test. The results from the study by Dave et al showed a poor outcome for patients with the molecular signature of BL treated with CHOP-like regimens,[47] emphasizing the importance of this distinction.

**Treatment**

The initial trials of BL treatment by using standard protocols failed to obtain acceptable outcomes. When BL was treated with conventional NHL or ALL regimens, the complete response rate ranged from 30% to 70%, with cure rates between 0% and 30%.[1-4] This might be attributed to the ability of viable tumor cells to recover and reenter the cell cycle with a rapid growth rate between chemotherapy cycles. The introduction of intensive chemotherapy given over a relatively short interval has provided a strategy to address this problem. However, the enhancement of response came at the cost of increased treatment toxicity, which was an acceptable compromise in pediatric patients but problematic in adults, especially the elderly. Most of the adult BL regimens have been adopted from pediatric protocols.[60-62] Although intensive chemotherapy improved outcomes markedly in pediatric BL, increased age was independently associated with inferior outcomes in most trials. Several pediatric regimens, such as the French LMB and German Multicenter Study Group for Adult ALL (GMALL) protocols, were attempted in adults early in the disease history. Both regimens achieved acceptable outcomes.

**B-NHL 83 and B-NHL 86**

The GMALL developed two protocols for adult BL derived from the pediatric Berlin-Frankfurt-Mnster (BFM) regimen. These protocols are B-NHL 83 (consisting of cyclophosphamide, prednisone, methotrexate, teniposide [Vumon], cytarabine, doxorubicin, and leucovorin, in six 5-day cycles) and B-NHL 86 (a similar regimen but substituting ifosfamide for cyclophosphamide in one phase, and dexamethasone for prednisone).[62] Trials investigating these protocols in adults reported 4- to 8-year overall survival rates of around 50%, which was a significant improvement compared to earlier outcomes. Nevertheless, toxicities were high with these regimens, including hematologic and neurologic toxicities, and 40% of patients could not complete the entire assigned regimen.

**LMB Protocol**

After the success that the LMB protocol had achieved in pediatrics, a retrospective review of 65 HIV-negative patients was conducted to evaluate its efficacy in the adult population. The LMB protocol includes a cytoreductive phase with the COP regimen (low dose cyclophosphamide, vincristine, and prednisone), followed by two induction cycles with COPADM (high dose of methotrexate, cyclophosphamide, vincristine, doxorubicin [Adriamycin], and prednisone), and then
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one to two consolidation cycles that contain cytarabine, and one to four maintenance cycles. The study involved previously untreated patients with small non–cleaved cell lymphoma or ALL L3. The majority of patients had advanced disease. Age ranged from 17 to 65. Approximately 89% of patients had a complete response, with a 3-year overall survival rate of 74%. The 3-year overall survival was 100% among patients with stage I/II disease, compared to 57% among patients with stage IV or ALL L3.[63] Subsequently, a prospective trial of LMB in adults was conducted on 51 patients (median age, 33). A complete response was achieved in 83% of patients, while 2-year event-free survival and overall survival were 61% and 66%, respectively. Multivariate analysis revealed an adverse outcome on survival rate associated with cytoreductive therapy failure and the presence of extranodal involvement.[64] A more recent phase II prospective trial of LMB in adults was published in 2005. The trial enrolled 72 adult patients with BL. A complete response rate of 72% was reported, with 2-year event-free and overall survival rates of 65% and 70%, respectively. Worse outcomes were noted in patients with increased lactate dehydrogenase level and older age. A 2-year overall survival of 84% was seen in patients aged < 33 years compared to 60% in patients > 33 years.[65] The most commonly reported adverse effect of the LMB protocol was myelosuppression.[63-65] Although employing the LMB protocol in adult BL has enhanced response and survival in this age group, the survival rate seen in pediatric patients was not achieved.

**CODOX-M/IVAC**

The CODOX-M/IVAC protocol, developed by Magrath, consists of alternating therapy between cyclophosphamide, vincristine (Oncovin), doxorubicin, high-dose methotrexate, plus intrathecal therapy, and ifosfamide, etoposide (VP-16), high-dose cytarabine (Ara-C), plus intrathecal therapy. Magrath and colleagues conducted a trial of four cycles of CODOX-M/IVAC on 41 patients, including children and adults, with small non–cleaved cell lymphoma. The study demonstrated a 2-year event-free survival rate of 92% in children as well as in adults. The investigators concluded that a similar prognosis can be obtained in adults and children when treated with CODOX-M/IVAC. However, the adults enrolled in this study were young (median age, 24). The reported major toxicities were mucositis and neurotoxicity.[61]

Two years later, Adde reported updated results obtained with four cycles of the alternating CODOX-M/IVAC protocol in advanced B-cell lymphomas. The regimen was given to 66 high-risk patients, including children and young adults; 55 patients had BL/BLL and 11 patients had DLBCL. The reported event-free survival was 85% at 1 year and beyond. Young adults were also included in this study (median age, 25).[66]

To establish the value of CODOX-M/IVAC protocol in adults, the UK Lymphoma Group conducted an international, prospective phase II study with some modification in the original protocol of CODOX-M/IVAC. The study enrolled 52 HIV-negative patients, with ages ranging from 16 to 60 years (median age, 35). Approximately 80% of these cases were considered high risk by International Prognostic Index–based criteria. Low-risk patients received three cycles of modified CODOX-M, whereas patients with high-risk parameters were given four cycles of alternating modified CODOX-M and IVAC. The 2-year overall and event-free survival rates for all patients were 73% and 65%, respectively. In the low-risk group, 2-year overall and event-free survival rates were 82% and 83%, respectively, vs 70% and 60% in high-risk patients. The study revealed a trend of worsening event-free survival in older patients and those with advanced disease. Reported side effects were myelosuppression and mucositis.[67]

A similar outcome was obtained in a small prospective study using a modified Magrath regimen, performed by Dana-Farber Cancer Institute. The 2-year event-free survival was 64% in the entire study, with 100% in low-risk patients vs 60% in high-risk patients. However, less toxicity was seen with this modified regimen compared to Magrath’s original protocol.[68]

**HyperCVAD With or Without Rituximab**

Investigators at The University of Texas M.D. Anderson Cancer Center developed the HyperCVAD protocol, which includes hyperfractionated cyclophosphamide, vincristine, doxorubicin (Adriamycin), dexamethasone, and CNS prophylaxis. A trial was conducted in 26 adult BL patients with a median age of 58. The complete response rate was 81%, and the 3-year overall survival was 49%. The study was performed in relatively elderly patients compared to earlier discussed studies, with 46% of patients older than 60 years.[69]

Since Burkitt cells strongly express CD20 on the surface, and rituximab is a monoclonal antibody against CD20, the introduction of rituximab to the preexisting regimens was investigated to improve survival in adult BL patients without worsening toxicity. A trial performed by Thomas et al revealed...
very promising results in elderly patients with BL. The study investigated the benefit of combining rituximab and HyperCVAD in 31 patients with BL. The median age was 46; 29% of patients were older than 60 years. The complete response rate was 86%, and the 3-year overall, event-free, and disease-free survival rates were 89%, 80%, and 88%, respectively. In patients older than 60 years, 3-year overall survival was 89%. In comparison to the HyperCVAD regimen in adults, HyperCVAD plus rituximab yielded a similar complete response rate but superior outcomes with regard to 3-year overall, event-free, and disease-free survival. The presence of CNS disease was not a prognostic factor in this study.[70]

NCCN Guidelines

The most recent National Comprehensive Cancer Network (NCCN) practice guidelines for NHL state that CHOP is an inadequate regimen for BL. Instead, the NCCN panel recommends using CODOX-M or HyperCVAD for the low-risk patient with BL, and CODOX-M/IVAC with or without rituximab, or HyperCVAD alternating with methotrexate plus cytarabine, with or without rituximab for the high-risk patient. The guidelines also note that stem cell transplantation should be considered for patients with relapsed disease.[71]

Bone Marrow Transplant

The role of autologous or allogeneic bone marrow transplant in adult BL is still controversial. Although some studies have reported that intensive therapy followed by stem cell transplant may improve survival,[72,73] it has not been accepted as a standard consolidation therapy. In a study investigating the efficacy of autologous transplants in adults with BL/ABL, a superior overall survival was obtained in treating relapsed chemosensitive disease. Compared to conventional regimens, the 3-year overall survival was 72% after the first complete remission, 37% in relapsed chemosensitive disease, and 7% in relapsed chemoresistant BL.[74] In a more recent study of chemoradiotherapy and transplant as primary therapy in sporadic BL, the 3-year event-free survival rate was 50%. [73] The potential benefit of graft-vs-lymphoma by using allogeneic transplant affected neither the relapse rate nor overall survival based on current data.[75-77] The place of autologous and allogeneic transplant in BL remains unclear.

Other Treatment Considerations

Recently, selective serotonin-reuptake inhibitors (SSRIs) were reported to have an apoptotic effect on B-cell derived tumors, including BL.[78,79] More recent experiments failed to find a specific effect on either malignant cells or any particular subtype of cells. Therefore, SSRIs are unlikely to represent a potential modality in BL therapy.[80] Central nervous system (CNS) prophylaxis is one of the main keys in BL treatment, since the CNS is a common site of relapse in the absence of such treatment. Prior to the introduction of intensive chemotherapy with CNS prophylaxis, CNS relapse occurred in 30% to 50% of patients with BL. High-dose systemic methotrexate or intrathecal methotrexate with or without cytarabine and hydrocortisone have been popular approaches to CNS prophylaxis. Because of the rapid cell turnover in BL, physicians should be aware of the significant risk of tumor lysis syndrome, particularly in patients with extensive disease. The syndrome can be lethal by creating metabolic derangement (eg, hyperkalemia) and renal failure. It should be prevented by identifying patients at risk, administration of prophylactic allopurinol, correction of preexisting electrolyte disturbances, and maintenance of aggressive fluid hydration to keep a high urine output. Electrolytes should be closely monitored throughout the initial course of treatment.REFERENCE GUIDE

Therapeutic Agents

| Allopurinol |
| Cyclophosphamide |
Treatment of BL in HIV-positive patients is beyond the scope of this review. However, there is a worse prognosis for BL in HIV-positive patients compared to HIV-negative patients. The immunocompromised state of the HIV-positive patients has precluded the use of intensive chemotherapy in the past. However, the introduction of HAART in HIV management allowed the application of more intense therapy. Recent successful clinical trials using intensive regimens have been reported.[65,81-83] In contrast to the encouraging results that rituximab has produced in HIV-negative adults with BL, the role of rituximab in HIV-positive BL remains controversial.[84,85]
Conclusion

Dramatic advances continue to be made in the diagnosis and treatment of Burkitt lymphoma. Rapidly identifying the correct diagnosis is necessary for the provision of optimal therapy. Therefore, clear criteria for diagnosis and the use of new modalities such as gene-expression profiles may need to be involved in uncertain cases. Treatment of adult BL has improved remarkably in the past few years with the introduction of very intensive “pediatric” or “acute leukemia” protocols. Delay in therapy can have tragic results, but with rapid diagnosis and the prompt initiation of an appropriate treatment regimen the majority of adults will be cured.

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Links: