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Cutaneous T-cell Lymphomas: 2021 update on diagnosis, risk-stratification, and management

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Disease overview: Cutaneous T-cell lymphomas are a heterogenous group of T-cell neoplasms involving the skin, the majority of which may be classified as Mycosis Fungoides (MF) or Sézary Syndrome (SS).

Diagnosis: The diagnosis of MF or SS requires the integration of clinical and histopathologic data.

Risk-adapted therapy: TNMB (tumor, node, metastasis, blood) staging remains the most important prognostic factor in MF/SS and forms the basis for a “risk-adapted,” multi-disciplinary approach to treatment. For patients with disease limited to the skin, expectant management or skin-directed therapies is preferred, as both disease-specific and overall survival for these patients is favorable. In contrast, patients with advanced-stage disease with significant nodal, visceral or blood involvement are generally approached with systemic therapies, including biologic-response modifiers, histone deacetylase inhibitors, or antibody-based strategies, in an escalating fashion. In highly-selected patients, allogeneic stem-cell transplantation may be considered, as this may be curative in some patients.

Disease Overview

Primary cutaneous lymphomas are a heterogeneous group of extranodal non-Hodgkin lymphomas that, by definition, are confined to the skin at diagnosis. The European Organization for Research and Treatment of Cancer (EORTC) and World Health Organization (WHO) published a consensus classification for cutaneous lymphomas in 2005 (1) that was recently updated (2). In contrast to nodal non-Hodgkin lymphoma, most of which are B-cell derived, approximately 75% of primary cutaneous lymphomas are T-cell derived, two-thirds of which may be classified as Mycosis fungoides (MF) or Sézary Syndrome (SS) (1, 3, 4). The incidence of cutaneous T-cell lymphomas (CTCL) has been increasing and is currently 6.4 per million persons, based on Surveillance, Epidemiology, and End Results (SEER) registry data, with the highest incidence rates being reported among men and African-Americans (3). Black patients with MF have key differences when compared to non-Black patients, including a female predominance, younger age of onset, and possibly inferior outcomes (5, 6). While CTCL may occur in children and young adults, this is very uncommon and often associated with histopathologic variants of MF (7-10). The incidence of CTCL increases significantly with age, with a median age at diagnosis in the mid-50's and a four-fold increase in incidence appreciated in patients over 70 (3, 9). Patients with CTCL have a higher incidence of secondary malignancies, including other non-Hodgkin lymphomas, lung cancer, bladder cancer, and melanoma, thus meriting appropriate screening (11, 12).

While genetic evidence strongly implicates UV radiation as a risk-factor for CTCL (13-15), epidemiological studies have failed to consistently identify other environmental

or virally associated risk factors for most CTCL subtypes, with the notable exception of HTLV-1 infection in adult T-cell leukemia/lymphoma (16). Recent studies, however, have suggested that medications may induce an antigen-driven T-cell lymphoproliferation or dyscrasia (17, 18). Moreover, as a variety of other medications may initiate a reaction mimicking MF, a careful medication history should be performed in these patients with a trial off any suspected offending drug. Individual genetic features have also been implicated in the development of CTCL. Rare reports of familial MF and the detection of specific HLA class II alleles in association with both sporadic and familial MF suggest that host genetic factors may contribute to MF development (19-21). While the role of environmental and host genetic factors in CTCL pathogenesis remains unclear, significant insights into disease ontogeny, molecular pathogenesis and disease-associated immune dysregulation have been realized (22-25). Recently performed next-generation sequencing studies have demonstrated a high frequency of C>T transitions, in contrast to the T>G transversions observed in B-cell lymphproliferative disorders, within NpCpC trinucleotides, a signature associated with ultraviolet B (UVB) exposure in melanoma [reviewed in (13)].

The cell of origin, molecular pathogenesis, and genetic landscape associated with MF/SS have been elucidated [reviewed in (26)], and have significant therapeutic implications [reviewed in (13)].

Diagnosis

Mycosis fungoides. The definitive diagnosis of MF, particularly patch/plaque stage disease, is challenging, as many of its clinical and pathologic features are non-specific

and overlap with reactive processes. Many patients will have had symptoms attributed to eczema, psoriasis or parapsoriasis for years prior to obtaining a definitive diagnosis. The median time from symptom onset to diagnosis in retrospective series is 3-4 years, but may exceed four decades (10, 27-29). Given the importance of clinicopathological correlation in the diagnosis of MF and the variable association of specific histologic findings with the diagnosis, biopsy reports are not infrequently “suggestive of” the diagnosis. This occasional uncertainty implied in biopsy reports and apparent lack of a more definitive histopathologic diagnosis may be a source of frustration for clinicians unfamiliar with the challenges associated with rendering a pathologic diagnosis of MF. Furthermore, treatment with skin-directed therapies at the time of biopsy, including topical corticosteroids, may diminish or eliminate neoplastic T-cells and other histopathologic findings, further compounding the diagnostic challenge, as these therapies diminish or eliminate neoplastic T cells and critical histopathologic findings for 2 to 4 weeks (30, 31). Drug reactions, chronic spongiotic dermatitis, connective tissue diseases, lichen sclerosus et atrophicus, and pigmented purpuric dermatoses are just a few of the conditions that may mimic MF (32, 33). While a definitive diagnosis of MF may be made based on clinical and histopathologic features alone, determination of T-cell clonality and assessment for the aberrant loss of T-cell antigen expression by immunohistochemical staining for CD2, CD3, CD5 and CD7 are useful ancillary studies in the diagnosis of MF (and SS). PCR-based methods are able to detect clonal rearrangements of the T-cell receptor (TCR) in formalin-fixed, paraffin-embedded biopsy specimens (34, 35). PCR-based methods, while sensitive, should be interpreted with caution, as clonal TCR gene rearrangements may be detected in normal elderly

individuals and in patients with benign dermatoses or other disease states (36-40). However, detection of identical clones from two different sites is quite specific for MF (41). Even this feature is not without complications as rare reactive processes display what appears to be an identical T-cell clone by PCR-based gene rearrangement studies in multiple biopsies over time. Moreover, some MF cases may not have a detectable T-cell clone (42). Recent studies have suggested that next generation sequencing (NGS) may be more sensitive and/or specific for assessing T-cell clonality in MF/SS, but NGS is not yet widely available (43-45). The extent to which MF/SS may be preceded by a pre-malignant state, analogous to monoclonal B-cell lymphocytosis (MBL) or monoclonal gammopathy of undetermined significance (MGUS), is debatable and poorly defined (46). The malignant lymphocytes in MF/SS are usually $CD3^+CD4^+$ and $CD8^-$, but frequently lose the expression of other pan-T-cell antigens. Therefore, demonstration of a significant population of $CD4^+$ cells lacking CD2, CD5, and/or CD7 expression is highly specific (specificity >90%) for MF in most reported series (47, 48). However, reactive dermatoses may also show a predominance of CD4-positive T-cells and loss to diminished expression of CD7, the T-cell antigen most frequently lost in MF, and these results must be interpreted with caution (33, 48). Finding a marked predominance of CD4-positive T-cells, especially by epidermotropic T-cells, helps to support a diagnosis of MF (33, 48). Similarly, finding extensive loss of CD7, preferential loss of pan T-cell antigens by epidermal T-cells, or loss of multiple pan T-cell markers favors a diagnosis of MF in challenging cases (33, 48). Clinically, patch/plaque stage MF is frequently characterized by persistent and progressive lesions that develop in a “bathing suit” distribution and vary in size, shape and color. These lesions are

frequently large (>5 cm), pruritic and multifocal in “classical” MF. In skin of color, lesions are polymorphic, including hyper- and hypopigmented patches/plaques. However, a broad range of MF variants have been described with differences in tropism (e.g. follicular MF), distribution (e.g. palmoplantar MF), pigmentation (e.g. hypo- and hyperpigmented variants) and focality (e.g. unilesional MF), some of which are formally recognized in the WHO-EORTC classification (1, 49). Histopathologically, patch/plaque MF is characterized by enlarged, epidermotropic lymphocytes with irregular nuclei that often show a band-like distribution in the dermis, where they are associated with dense strips of collagen (“wiry” fibrosis). Aggregates of neoplastic T-cells in the epidermis, termed Pautrier microabscesses, are seen in a minority of cases, but are a helpful clue to the diagnosis. Folliculotropism and/or syringotropism may be seen in a minority of cases. Given the need for uniform diagnostic criteria in MF, the International Society for Cutaneous Lymphoma (ISCL) proposed a point-based diagnostic algorithm which integrates clinical, histopathologic and immunophenotyping data with an assessment of T-cell clonality (32). Recent studies have demonstrated that the inclusion of clinical information, including photographs, improved the diagnostic accuracy of pathologists, thus highlighting the importance of clinical information for accurate histopathologic diagnosis (50, 51).

Sézary Syndrome. Traditionally, SS is defined as a leukemic form of CTCL associated with erythroderma, intractable pruritis, ectropion, and palmoplantar keratoderma. A series of studies in the early to mid-20th century, beginning with Sezary’s initial landmark observation in 1938, identified a population of large lymphocytes in the peripheral blood with grooved, lobulated (that is, “cerebriform”)

nuclei in patients with MF or SS (52-57). As in other chronic lymphoproliferative disorders, the Sezary cell count is preferably expressed in absolute terms, with ≥1000 cells/µl classified as B2 disease in the current ISCL/EORTC TNMB staging classification. The morphologic detection of Sezary cells in the peripheral blood is not specific for CTCL, as Sezary cells may be found in peripheral blood from normal donors and in benign conditions (58-60). The histopathologic findings in the skin often resemble those observed in MF, with less prominent epidermotropism, though findings in skin biopsies may be paradoxically subtle and non-specific. As in MF, immunohistochemical studies showing a CD4 predominance and loss of pan T-cell markers may be helpful. Lymph node involvement is characterized by complete effacement of the nodal architecture by infiltrating Sezary cells (61).

In SS, clonal T cells are generally $CD3^{+}CD4^{+}$ and $CD8^{-}$ by multi-color flow cytometry (62-65). As in MF, the aberrant loss of pan-T-cell antigens, including CD2, CD3, CD4, CD5, CD7 and/or CD26 is frequently observed (64, 66-69). Of these, the aberrant loss of CD7 and/or CD26 expression is most common, being observed in most cases (65, 66, 70-74). The loss of CD7 (≥40%) and/or CD26 (≥80%) is sensitive (>80%) and highly specific (100%) for SS (69). The EORTC cutaneous lymphoma task force has defined the B2 blood group as an absolute count of either CD4+CD7- or CD4+CD26- T-cells ≥1000/µL plus a T-cell blood clone (75). However, the International Clinical Cytometry Society (ICCS) has recently recommended that peripheral blood flow cytometry also include assessment of phenotypic aberrancies in other T-cell markers, leading to improved diagnostic accuracy (76, 77). The aberrant expression of the MHC class I-binding, killer immunoglobulin-like receptor (KIR) CD158κ (and less commonly

CD158a or CD158b), normally expressed by natural killer cells, was described in the majority of patients examined with SS (69, 78, 79). Molecular studies, including detection of a clonal TCR gene rearrangement by PCR and the presence of a clonal cytogenetic abnormality, provide evidence of T-cell clonality. An alternative approach to demonstrate T-cell clonality incorporates multi-color flow cytometry using a panel of antibodies specific for various TCR beta-chain variable region family members (TCR-Vβ) (80-82). This approach is successful in identifying a clonal population of T cells if this population is significantly higher than the background frequency of polyclonal T cells harboring the same Vβ chain (80, 81, 83).

The currently proposed ISCL criteria for SS integrate clinical, histopathologic, immunophenotyping and molecular studies. In patients with erythroderma, criteria recommended for the diagnosis of SS by the ISCL include the following: absolute sezary count ≥1000/μl, a CD4/CD8 ratio ≥10, (due to the clonal expansion of $CD4^+$ cells), aberrant expression of pan-T-cell antigens (i.e. loss of CD7 and/or CD26 expression in at least 40% or 30% of cells, respectively), demonstration of T-cell clonality by Southern blot or PCR-based methods, or cytogenetic demonstration of an abnormal clone (64). At a minimum, the WHO-EORTC recommends the demonstration of T-cell clonality in combination with the above-mentioned criteria for the diagnosis of SS (1). In addition to the ISCL criteria, the most recent WHO classification requires erythroderma, generalized lymphadenopathy, and clonally related T-cells (Sézary cells) in the skin, peripheral blood, and lymph nodes. On rare occasions, SS may be preceded by a prior history of classic MF. The ISCL recommends that such cases be designated as SS preceded by MF or secondary erythrodermic CTCL Conversely, patients with

MF, but without erythroderma, may meet hematologic criteria for SS. In these cases, the designation “MF with leukemic involvement” is recommended, although genetic features of both MF and SS have been recently described in patients with SS preceded by MF (15).

Non-MF/SS subtypes of CTCL. An important goal during a patient’s initial diagnostic evaluation is to distinguish non-MF/SS CTCL subtypes from MF/SS, as the natural history, prognosis, and treatment approach for each of the non-MF/SS lymphomas is highly variable. A detailed description of these CTCL subtypes is beyond the scope of this update, but the salient features of each have been previously summarized (2, 84).

Risk-stratification

Staging. In contrast to many other lymphoproliferative disorders in which cytogenetic and laboratory findings play a prominent role in risk stratification, TNMB (tumor, node, metastasis, blood) staging remains an important prognostic factor in MF/SS and forms the basis for a “risk-adapted” approach to treatment. In 2007, the ISCL and EORTC revised the TNMB staging of MF/SS (85). Patients with only patches and plaques have stage I disease, but may be further divided into stage IA (<10% body surface area involved or T1) or stage IB (>10% body surface area involved or T2) based on the extent of skin involvement, and by the presence of patch- (T1a/T2a) or plaque-stage (T1b/T2b) disease. For practical purposes, the area of a patient’s hand (including both palm and digits) represents approximately 1% of body surface area. Current staging and diagnostic recommendations do not require a biopsy of clinically normal

lymph nodes; however, an excisional biopsy of any abnormal lymph nodes (≥1.5 cm in diameter or firm/fixed) is recommended, with preference being given either to the largest lymph node draining an area of skin involvement or to the node with the greatest standardized uptake value (SUV) on FDG-PET imaging(86-88). While radiologic examination of lymph nodes is considered optional for patients with T1 or T2 disease and no evidence of lymphadenopathy on physical examination (85), a recent international study found that physical examination may miss radiographically-enlarged lymph nodes leading to significant changes in staging in a minority of patients, particularly those with plaques (89). Patients with patch/plaque stage disease (T1/T2) and architectural preservation of any clinically abnormal lymph nodes are classified as stage IIA. Collectively, patients with stage I-IIA disease have “limited (or early)-stage” disease, as the overall survival in these patients is measured in decades, with survival in patients with stage IA disease resembling that of normal age-matched controls (9, 27, 28). At diagnosis, the majority of MF patients will have limited-stage disease (9). In contrast, patients with tumor stage disease (T3), erythroderma (T4), nodal involvement characterized by partial or complete architectural effacement (N3), visceral metastases (M1), or significant leukemic involvement (B2) have “advanced (or late)-stage” disease. Detection of a clonal TCR gene rearrangement by PCR, which has been incorporated into the revised ISCL/EORTC node(N) and blood(B) staging classification, is an adverse prognostic factor (9, 90-93). Unfortunately, median survivals from approximately 1-5 years are observed in these patients with more extensive disease (9). The revised ISCL/EORTC staging for MF/SS is summarized in Table 1.

A retrospective study including 1,398 MF patients, 71% with patch/plaque stage disease, and 104 SS patients has validated the revised ISCL/EORTC staging classification (9). On univariate and multivariate analyses, the revised T, N, M and B classification were significantly associated with overall and disease-specific survival. The median survival, disease-specific survival and risk of disease progression, by clinical stage, are summarized in Table 1. A recent metaanalysis reported a similar trend for 5-year survival (94). While the impact of recently approved agents on overall survival is uncertain, the rather durable responses observed in subsets of patients treated with these agents may provide ample reason for optimism. For those with early-stage disease, male gender, age >60, plaque-stage or folliculotropic disease, and nodal stage N1/Nx were adverse prognostic factors and were utilized to generate the cutaneous lymphoma international prognostic index (CLIPi) for patients with early-stage disease (95). Ten-year OS was 90.3% for those with low-risk (0-1 risk factors) disease and 48.9% for those with high-risk (3-5 risk factors) disease. Similarly, male gender, age >60, stage B1/B2 or N2/N3 disease, and visceral involvement were adverse prognostic factors for patients with late-stage disease. Ten-year OS was 53.2% for low-risk patients, and 15.0% for high-risk patients (95). In a large, international series (n=1,275) of late-stage MF/SS, stage IV disease, age >60, large-cell transformation, and elevated LDH were identified as independent adverse prognostic factors, and were similarly combined in a prognostic index (96). Patients with low-risk (0-1 risk factors) disease experienced superior 5-year OS (68%) compared with the 5-year OS observed (28%) among those with high-risk (3-4 risk factors) disease. (9, 97-101)An alternative staging system has been proposed for those with folliculotrophic MF and identifies a subset of

patients with limited cutaneous involvement and a more favorable prognosis (102, 103).Given the importance of the TNMB classification in risk stratification and defining disease burden, the ISCL/EORTC recommends its use in defining the initial, maximum and current burden of disease, which will ultimately play an important role in the selection of either skin-directed or systemic therapies (85). In the future, it is anticipated that improved understanding of the genetic landscape will further improve risk-stratification and lead to a more personalized approach for treatment selection in CTCL (13).

Recognizing that the staging system used for MF/SS is less helpful for non-MF/SS cutaneous lymphomas, a new TNM classification was also proposed for these CTCL variants (104). Due to the significant heterogeneity of these lymphomas, this staging system does not provide prognostic information, but is intended to provide a uniform description of the disease burden.

Treatment of limited-stage MF

As the majority of CTCL patients present with patch/plaque stage MF and have an excellent prognosis, the initial goal of therapy is to improve symptoms and quality of life while avoiding treatment-related toxicity. For many patients, this may involve either expectant management (i.e. “watch and wait”) or skin-directed therapies. A randomized trial comparing early combined modality therapy, including both radiation and multiagent chemotherapy (cyclophosphamide, doxorubicin, etoposide, and vincristine), with sequential topical therapies demonstrated that combined-modality therapy, while associated with a superior complete response rate, did not translate into improvements

in disease-free or overall survival and was associated with significant toxicity (105). Moreover, an international prospective study compared skin-directed therapies (topical steroids, ultraviolet B, psoralen and ultraviolet A, topical nitrogen mustard, topical carmustine and local radiotherapy) to systemic therapy (oral retinoids, oral bexarotene, methotrexate, interferon and extracorporeal photochemotherapy) in early-stage MF. Patients receiving skin-directed therapy had a superior overall response rate (106). The limited efficacy associated with chemotherapy has been highlighted in retrospective studies in which the median time to next treatment following single or multiagent chemotherapy was ≤4 months(107, 108). Therefore, patients with limited-stage disease who require therapy are best approached with skin-directed therapies, usually under the direction of a dermatologist and/or radiation oncologist. Excellent reviews and treatment guidelines are available (84, 109-114).

Topical therapies. The first-line treatment for limited stage MF is topical steroids. In an uncontrolled prospective study, topical clobetasol propionate was used in 85% of patients with stage 1A/B disease, had an overall response rate of 94%, and is associated with minimal to no toxicity (115, 116). An alternative topical medication is mechlorethamine 0.02% gel (117). In a phase 2 trial, patients with stage IA-IIA MF were treated with 0.02% gel daily for up to 12 months. A response was observed in 58.5% of patients, with 13.8% achieving a complete response. A sustained response was observed in 85.5% patients and the most common adverse effects are contact dermatitis and irritant dermatitis (118). For refractory and persistent cutaneous lesions, bexarotene 1 % topical gel may be considered. Prospective trials have demonstrated an ORR between 44% and 63% (119). Topical toll-like receptor (TLR) agonists, which lead

to local production of interferons, and other cytokines, induce cell death and promote host anti-tumor immunity (120), and have demonstrated efficacy in limited stage MF. For example, 20 patients with stage 1A-2B disease were treated with 5% Imiquimod, a TLR7 agonist, and an ORR of 80%, including 45% complete responses, were observed. Toxicities are limited, including localized pain, redness, ulceration, and pruritus. Systemic symptoms, including flu-like symptoms and fatigue, while reported, are rare. Most adverse events are self-limited and resolve after the first few weeks of treatment (120, 121). Resiquimod, a potent TLR7/8 agonist, was examined in a phase 1 trial using 0.03 and 0.06% topical resiquimod gel. Among the 12 patients treated, clinical improvement was observed in 75% of treated lesions and 90% of patients had a reduction in malignant T cell clones in the treated lesions, and an abscopal, and presumably immune-mediated, effect was observed (122).

Phototherapy. Phototherapy is an important treatment modality that may be used alone, or in combination with topical therapies, in patients with limited-stage disease, and includes narrowband UVB (NBUVB, 311nm) and 8-methoxypsoralen plus ultraviolet A (PUVA). NBUVB is used in both patch and plaque stage MF. PUVA is the modality of choice in skin of color. Phototherapy is widely available and has demonstrated efficacy in many retrospective and prospective studies (31, 123), and a comprehensive consensus statement on the use of phototherapy was recently published (124).

Radiation. MF/SS are radiosensitive, thus radiation therapy, with curative intent, may be considered in patients with localized, unilesional MF. For those with more

widespread disease, palliative local radiation or low-dose total skin electron beam therapy (TSEBT) are effective [(125), reviewed in (126), (127)].

Treatment of advanced-stage MF/SS

Overview. Patients with advanced-stage MF/SS require a multidisciplinary approach, as various combinations of skin-directed therapies, biologic-response modifiers and ultimately the sequential use of systemic chemotherapeutic agents are frequently employed in the management of these patients. As for limited-stage disease, multiagent chemotherapy, with only few exceptions, is generally not appropriate (105). A “risk-adapted” stage-based approach, consistent with NCCN guidelines, is adopted, with biologic-response modifiers (e.g. bexarotene and interferon-alpha) and histone deacetylase inhibitors (e.g. romidepsin, vorinostat) generally preferred prior to escalating therapy to include systemic chemotherapy (128). Therapeutic decisions are individualized and based on a patient’s age, performance status, extent of disease burden, the rate of disease progression, and previous therapies (109-114).

Bexarotene. The endogenous retinoids all-*trans* retinoic acid and 9-*cis* retinoic acid (i.e. vitamin-A-derived compounds) regulate a diverse array of biologic processes, ranging from embryonic development to cell growth, differentiation and survival, upon binding two families of steroid hormone receptors, the retinoic acid receptors (RAR) and retinoid X receptors (RXR). Upon forming homo- or heterodimers, these receptors recruit various nuclear co-repressor or co-activator proteins depending whether or not they are bound by ligand. Multiple RAR retinoids have been used in MF/SS, either topically or systemically (reviewed in (129, 130)), with response rates exceeding 50%.

However, in 1999 the oral RXR-selective “rexinoid” bexarotene was FDA approved for CTCL and was later approved as a topical gel formulation. Laboratory studies demonstrate that bexarotene promotes cell cycle arrest and apoptosis in CTCL cell lines (131, 132). In a multicenter phase II-III study, 94 patients with advanced-stage CTCL who had been previously treated with a median of five prior therapies, the vast majority of whom had disease refractory to at least one prior systemic therapy, received at least 300 mg/m^2 of oral bexarotene daily (133). Among patients treated at the 300 mg/m^2 dose, an overall response rate of 45% was observed, only 2% of which were complete. While an improved overall response rate was noted with the use of higher doses, this difference was not statistically significant, and dose-limiting toxicity was far more common (50% vs. 89%) in these patients. While a dose-response relationship is likely, the 300 mg/m^2 dose appears to provide the optimal risk-benefit ratio. The most common toxicities associated with therapy were hypertriglyceridemia (in 82%) and central hypothyroidism (29%). Myelosuppression is infrequent and usually uncomplicated. Pancreatitis secondary to hypertriglyceridemia may be rarely observed, but is reversible upon discontinuation of treatment. Therefore, a baseline lipid panel and free T4/TSH should be obtained prior to the initiation of therapy. In one retrospective study, all patients treated with bexarotene developed hyperlipidemia and central hypothyroidism, frequently within weeks of initiating treatment (134). Consequently, use of lipid-lowering agents (e.g. fenofibrate) and low-dose levothyroxine (e.g. 50 micrograms) prior to initiating bexarotene is generally recommended (135-137). In clinical practice, bexarotene is frequently initiated at a lower dose of 150 mg/m^2 and subsequently titrated to full doses after 4 weeks of therapy, depending upon patient

tolerability. Most responses occur within 2-3 months of treatment initiation, but may be delayed. Therefore, in the absence of disease progression or toxicity, treatment should be continued for up to 6 months. For responding patients, treatment should be continued until disease progression and, depending upon the quality of the response, adjunctive skin-directed therapies (e.g. NB-UVB, PUVA) should be considered (138). Guidelines describing appropriate laboratory monitoring, supportive care, and safe clinical prescribing of bexarotene have been recently published (137). Future studies clarifying the optimal use of bexarotene, either in combination or sequentially with other agents, are needed.

HDAC inhibitors. Histone deacetylases (HDACs) catalyze the removal of acetyl groups from both histone and non-histone proteins. As histone acetylation is associated with an open chromatin configuration associated with active gene transcription, HDACs contribute to histone deacetylation and the epigenetic repression of gene transcription. As HDACs regulate a wide variety of processes involved in carcinogenesis, multiple mechanisms may explain the clinical activity of HDAC inhibitors (139, 140), including altered gene expression of cell-cycle and apoptotic regulatory proteins (141-145), acetylation of non-histone proteins regulating cell growth and survival (146-149), angiogenesis (150, 151), aggresome formation (152) and DNA repair (153). In addition, HDAC inhibitors have profound effects on the tumor microenvironment in CTCL (154).

Vorinostat (suberoylanilide hydroxamic acid, SAHA) and romidepsin (depsipeptide) inhibit class I and II HDACs (i.e. pan-HDAC inhibitors), the former being widely expressed in various lymphoma subtypes (155). Early phase I studies of both vorinostat and romidepsin established their safety and potential efficacy in

lymphoproliferative disorders, including CTCL (156), thus paving the way for larger phase II studies. An earlier phase II study established 400 mg of oral vorinostat once daily as the optimal dose that was investigated further in 74 previously treated patients with CTCL, most of whom (>80%) had advanced-stage disease (157, 158). The overall response rate was approximately 30% for patients with advanced-stage disease and was associated with a median duration of response estimated to exceed 185 days. However, it is noteworthy that the reported response rate observed with vorinostat, using updated response criteria, was considerably lower (i.e. <10%) in MAVORIC (159). Most responses were rapid (i.e. <2 months) and were also noted in patients with tumor-stage disease and Sézary syndrome (160). Patients who failed to achieve an objective response appeared to derive some clinical benefit, including stable disease, decreased lymphadenopathy and pruritis relief, with treatment. The most common non-hematologic adverse events, observed in almost 50% of patients, were gastrointestinal toxicities (nausea, vomiting, diarrhea). Hematologic toxicities, including anemia or thrombocytopenia, were observed in up to 20% of patients. Among responding patients, long-term therapy with vorinostat appears to be well tolerated (161). Prolongation of the QT interval was rarely observed, but monitoring and appropriate electrolyte replacement is recommended for those patients at risk for QT prolongation (162).

Romidepsin, administered as a 4-hour intravenous infusion (14 mg/m^2) days 1, 8 and 15 every 4 weeks, was evaluated in two phase II studies, the largest of which included 96 patients, most with advanced-stage disease(163, 164). The overall response rate was 38% for patients with advanced-stage disease, with a median

duration of response that exceeded one year. A toxicity profile similar to that described for vorinostat was observed. Intensive cardiac monitoring in a subset of these patients failed to demonstrate any clinically significant cardiotoxicity (165). A subset of MF/SS patients, after induction with romidepsin at the standard dose, may anticipate a durable remission with attenuated "maintenance" (every 2- or 4-week) dosing. For example, among 38 MF/SS patients, 17 achieved a durable (>6 month) remission, 9 of which were maintained with an attenuated, dose-sparing schedule (166). Among the patients achieving a durable remission, the median duration of treatment was 15 months (range: 7-34 months).

Additional HDAC inhibitors, including potent pan-HDAC inhibitors, appear to have activity in CTCL (145, 167, 168). Further studies are needed to fully define the mechanisms of resistance to HDAC inhibition in CTCL (145, 169-173), enabling the development of rational therapeutic combinations incorporating HDAC inhibitors in CTCL (174, 175).

Interferons. Interferons (i.e. interferon alpha-2b, interferon gamma-1b), have pleiotropic and immunomodulatory effects in CTCL and are associated with an overall response rates as high as 50-70% and a complete response rate of 20-30%, particularly in patients with limited-stage disease (176-180). While often considered as second-line therapy for limited-stage CTCL, interferon-alpha, frequently at doses ranging from 3-10 million units daily to three times weekly, is a treatment to be considered in the first-line setting in patients with advanced-stage disease. Responses, which may be achieved within a few months, are observed in patients with tumor-stage MF and SS, and are occasionally durable(107, 181). Furthermore, interferon-alpha may be successfully

combined with a number of other therapeutic modalities frequently utilized in the management of these patients, including PUVA, bexarotene, chemotherapy and ECP (182-195). For example, in a cohort of 51, mostly advanced-stage patients treated with single-agent, low-dose, interferon-alpha, responses were observed in 34 (67%), including 21 (41%) with a complete response and 9 with a long-term remission (179). Similarly, in a cohort of 47 patients with stage III/IV disease, 89% of whom had peripheral blood involvement, a response rate exceeding 80% was observed in those treated with a combination of ECP and interferon-alpha (195). Interferon-alpha is associated with myelosuppression, transaminitis and dose-limiting flu-like side effects, particularly at higher doses.

Extracorporeal photophoresis. During extracorporeal photophoresis (ECP) pooled leukapheresis and plasmapheresis products are exposed to 8-methoxypsoralen (8-MOP) prior to extracorporeal circulation through a 1 mm thick disposable cassette exposed to UVA radiation. The irradiated leukocytes, representing approximately 5% of peripheral blood leukocytes, are subsequently reinfused. Psoralen covalently binds and crosslinks DNA following UVA exposure, leading to the induction of apoptosis in the majority of treated lymphocytes by multiple mechanisms involving bcl-2 family members, disruption of the mitochondrial membrane potential and extrinsic cell death pathways (196-198). In contrast, ECP leads to monocyte activation, including significant changes in gene expression (199), and dendritic cell differentiation, which is thought to culminate in enhanced antigen presentation and the initiation of a host immune response (200).

Following the landmark study by Edelson and colleagues describing responses in 27 out of 37 patients with erythrodermic CTCL treated with ECP, ECP was approved by the Food and Drug Administration of the USA for the treatment of CTCL and is now considered the treatment of choice in the first-line management of patients with Sézary syndrome in many centers (201). Furthermore, retrospective series demonstrate that ECP is associated with superior time to next treatment when compared with most systemic therapies, including HDAC inhibitors (108). While responses vary between case series, overall response rates hover around 60%, with a complete response rate of approximately 20% (202-205). As current treatment protocols no longer require the oral administration of 8-MOP, eliminating nausea, ECP is safe and generally very well tolerated. Long-term use of ECP may cause iron deficiency anemia due to the small residual blood volume that is not returned to the patient (206). While the precise mechanism of action is incompletely understood, evidence suggests that ECP has immunomodulatory effects which may augment host anti-tumor immunity (207, 208). It is not surprising then that the median time to response following the initiation of ECP is approximately 6 months. Median survival exceeding 8 years has been observed in ECP treated patients and among complete responders, many experience durable responses which may permit, for some, weaning from CTCL-directed therapies (202, 209-211). In a retrospective study, patients treated with ECP early (i.e. within the first 3 lines of therapy) experienced superior median time to next treatment (approaching 4 years) when compared to either those treated with alternative agents or ECP later in the course of therapy (212). While patient- or disease-specific factors which may predict a response to therapy are imperfect (213), Sezary patients without significant nodal or

visceral disease who initiate ECP promptly after diagnosis may be more likely to respond. In addition, patients without profound immune deficiencies, reflected by normal or near-normal cytotoxic T-cell and CD4/CD8 values and the absence of prior exposure to systemic chemotherapy, may be more likely to respond to therapy (202, 204, 210). While effective as monotherapy, ECP has also been combined with other therapeutic strategies, including interferon, bexarotene and TSEBT (185, 195, 209, 214-216).

Monoclonal antibodies and immunotoxins. In contrast to many B-cell lymphoproliferative disorders, where the incorporation of CD20-targeting monoclonal antibodies has become the standard of care, additional studies are needed to identify the optimal approach targeting T-cell specific antigens in advanced-stage MF/SS. Alemtuzumab is a humanized IgG1 monoclonal antibody directed against CD52, an antigen widely expressed by B-cells, T-cells and monocytes (217). In a phase II study in 22 patients with advanced-stage MF/SS, overall and complete response rates of 55% and 32%, respectively, were observed, with a median time to treatment failure of 1 year (218). Given the significant risk of infectious complications, low-dose subcutaneous alemtuzumab was investigated in 14 patients with SS, most of whom had relapsed/refractory disease (219). Most patients in this study received 3 mg of subcutaneous alemtuzumab on day 1 followed by a 10 mg dose on alternating days until the Sézary count was $<1000/mm^3$. With the exception of a single patient whose best response was stable disease, 9 out of 10 patients treated in this manner achieved a response, 3 of which were complete. For most patients, the time to treatment failure exceeded 12 months. What is notable, however, is that infectious complications were

not observed in patients treated with the lowest dose (i.e. 10 mg) of alemtuzumab. Similar results, with no infectious complications, were recently reported in a small cohort of patients treated with modified, low-dose, subcutaneous alemtuzumab for six weeks (220). In addition to hematologic toxicity, conventionally dosed alemtuzumab in advanced-stage MF/SS is associated with a high incidence of infectious complications (218, 219, 221-224). Overall, infectious complications have been observed in two-thirds of treated patients, most of which are bacterial, including sepsis. Cytomegalovirus (CMV) reactivation is the most common viral infection. In addition, *Pneumocystis jirovecii* pneumonia and invasive fungal infections have also been observed. Therefore, trimethoprim-sulphamethoxazole and acyclovir should be routinely administered for PJP and HSV/VZV prophylaxis, respectively, in patients receiving alemtuzumab. In addition, CMV surveillance should be performed every 1-2 weeks by quantitative PCR and suppressive therapy with ganciclovir or oral valganciclovir initiated in response to viral reactivation. Low-dose, subcutaneous alemtuzumab appears to be safe and efficacious in selected patients with advanced-stage MF/SS provided with appropriate supportive care. Monoclonal antibodies targeting additional T-cell specific antigens, including CD2 (225), CD4 (226), CD25 (227) and CCR4 (228-230) are being explored and appear promising. Resimmune, a second-generation immunotoxin in which the catalytic and translocation domains of diphtheria toxin (DT_{390}) have been fused to CD3-specific single chain antibody fragments [bisFv(UCHT1)], is associated with a response rate of 36% (16% complete), and is particularly active in patients with limited-stage disease (231). Much like its predecessor, resimmune is associated with a vascular leak syndrome (84).

Mogamulizumab. Mogamulizumab (KW-0761) is a humanized monoclonal antibody specific for the chemokine receptor CCR4 that has been defucosylated and is consequently associated with enhanced antibody-dependent cell-mediated cytotoxicity (ADCC). In a phase I/2 study, mogamulizumab was well tolerated and was associated with an overall response rate of 37%. A similar response rate of 29% (2/7), all partial, was observed in a phase II Japanese study (230, 232). In addition to ADCC-mediated clearance of malignant T cells, mogamulizumab may inhibit T_{reg}-mediate immune suppression (233, 234), and may warrant further investigation with immunomodulatory therapies, including immune checkpoint blockade (235). A randomized, phase III clinical trial comparing mogamulizumab and vorinostat in relapsed/refractory CTCL (MAVORIC) demonstrated a significant improvement in progression-free survival among MF/SS patients randomized to mogamulizumab (159). Overall responses in patients treated with mogamulizumab were higher in the blood compartment (68%) when compared with those observed in the skin (42%) or lymph nodes (17%). Not surprisingly then, the overall response rate was highest among Sezary syndrome patients (37%). Overall, treatment with mogamulizumab was well tolerated, with few ≥grade 3 adverse events (AE's). Infusion-related reactions were the most common grade 1 or 2 AE's and were observed in 32%. Mogamulizumab-associated rashes are observed, and may clinically and histopathologically mimic CTCL, but may be managed without discontinuation of therapy (236). These positive findings led to mogamulizumab's approval by the FDA in 2018 for MF/SS patients who have failed at least one prior systemic therapy.

Brentuximab vedotin. Given the promising response rates observed with brentuximab vedotin (BV) in phase II studies (237, 238), a randomized, phase III clinical trial (ALCANZA) comparing BV with an investigator's choice (methotrexate or bexarotene) was performed, and demonstrated a significantly improved PFS (>12 months vs. 3.5 months) for patients randomized to BV, and led to its FDA approval in previously treated CTCL (239, 240). Among MF patients with limited-stage disease treated with BV, a response lasting at least 4 months (ORR4) was observed in 40%, whereas an ORR4 of 63% was observed among patients with tumor-stage (stage IIB) disease. Consistent with prior experience in "CD30 high" lymphomas, an ORR4 of 89% was observed among patients with primary cutaneous ALCL with disease confined to the skin.

Checkpoint blockade. Durable remissions may be achieved with immunomodulatory therapies, including ECP and interferon-α. While largely anecdotal, these observations suggest that host immunity, when properly harnessed, can lead to durable responses in selected patients. These observations, coupled with high-level PD-L1 expression in a substantial minority of patients, provide a strong rationale for checkpoint blockade (CPB) in CTCL (241, 242). While few CTCL patients have been included in early phase clinical trials, durable responses have been observed, including two responding CTCL patients who achieved responses that were ongoing at 24+ and 50+ weeks (243). In a phase II study in heavily pretreated patients, an overall response rate of 38% was observed in advanced-stage patients treated with pembrolizumab (244). These encouraging preliminary results, in conjunction with the smorgasbord of

currently available immunomodulatory agents, lend themselves to future and ongoing combinatorial strategies (242).

Systemic Chemotherapy. Responses to conventional chemotherapeutic agents are rarely durable in CTCL (84), being associated with a median time-to-next treatment that is measured in months (107, 108). Consequently, >90% of patients treated in this manner will require additional therapy within the first year of therapy. Furthermore, first-line treatment with systemic chemotherapy has been associated with increased mortality (245). Therefore, multiagent chemotherapy is rarely utilized. Therefore, novel therapeutic agents, including clinical trial participation, are preferred. As there is no standard of care for patients with MF/SS requiring systemic chemotherapy and the decision to initiate therapy is individualized, including consideration of responses and complications related to prior therapies, participation in a well-designed clinical trial is always worth consideration.

Pralatrexate, a novel antifolate with a high affinity for the reduced folate carrier (RFC-1) and novel mechanism of resistance when compared with methotrexate (246-248), was associated with an overall response rate of 29% in the PROPEL study. This study was comprised largely of peripheral T-cell lymphoma patients, most of whom had refractory disease (249). Notably, twelve patients with transformed MF were included in the study (250). Many of these patients had received more than 5 prior systemic therapies, including CHOP or CHOP-like regimens. With only a single exception, these patients were refractory to their most recent therapy. Responses, as assessed by the study investigators, were observed in 58% of patients with a median duration of response and progression-free survival of 4-5 months. Results of a dose-finding study

were reported in a larger cohort of CTCL patients (251). In this study, the optimal dose was identified as 15 mg/m^2, given weekly 3 weeks out of 4, and was associated with an overall response rate of 43%. In an effort to reduce the incidence of mucositis, folic acid and vitamin B12 supplementation is routinely provided in these patients (252). Additional therapeutic approaches, including proteasome inhibition (253), immunomodulatory strategies (254), and more targeted approaches warrant further investigation (255, 256).

High-dose chemotherapy and hematopoietic stem cell transplantation. The available experience with high-dose chemotherapy and autologous stem cell transplantation, largely confined to case series, suggests that responses following treatment are frequently transient. In contrast, the durable remissions observed following allogeneic transplantation may be explained by the graft versus lymphoma immune response (257, 258). A retrospective analysis of 60 patients with advanced-stage MF/SS who underwent allogeneic stem cell transplantation was recently reported (259). In this series, patients had received a median of 4 prior therapies prior to undergoing either reduced-conditioning (73%) or myeloablative (27%) conditioning prior to related (75%) or matched-unrelated donor (25%) transplantation. Non-relapse mortality at 1 year was 14% for patients receiving reduced-intensity conditioning or HLA identical/related donor stem cells and 38-40% for those undergoing myeloablative conditioning or receiving match-unrelated donor grafts. Transplantation during an early phase of disease (defined as first or second remission or relapse following 3 or fewer systemic therapies) was associated with lower relapse rates (25% vs. 44% at 1 year) and a statistically insignificant increase in 3-year overall survival (68% vs. 46%). Given

the differences in non-relapse mortality, both reduced-intensity conditioning and use of matched-related donors were associated with superior overall survival (63% at 3 years). Seventeen out of 26 patients who relapsed received donor-lymphocyte infusions. Of these, 47% achieved a complete remission, thus providing evidence for a graft-versus-lymphoma effect in MF/SS. The estimated 3-year progression-free and overall survival were 34% and 53%, respectively. A more recent update of the EBMT experience again demonstrates that allogeneic stem-cell transplantation is curative in a minority of patients, but non-relapse mortality and disease progression remain challenging (260).Similar outcomes have been observed in a large series from the CIBMTR (n=129), as non-relapse mortality and disease progression at 1 year were 19% and 50%, respectively, and 5-year PFS and OS were 17% and 32%, respectively (261). Given the possibility of complete and durable remissions, allogeneic stem-cell transplantation may be considered in highly selected patients(181, 262, 263).

Summary. Establishing a definitive diagnosis of CTCL, accurate disease staging and risk-stratification, and the selection of appropriate therapy requires a multidisciplinary approach. While high response rates may be achieved with systemic chemotherapy, these responses are frequently short-lived and associated with significant toxicities. As treatment of advanced-stage MF/SS is largely palliative, a stage-based approach utilizing sequential therapies in an escalated fashion is preferred. Participation in a well-designed clinical trial is encouraged, as the introduction of novel agents will continue to expand the therapeutic options available in the management of CTCL.

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TABLE 1. ISCL/EORTC Staging

	TNMB Classification				Median	10-year(9)		
Stage	**T**	**N**	**M**	**B**	**OS (years)**	**OS (%)**	**DSS (%)**	**RDP (%)**
IA	1	0	0	0,1	35.5	88	95	12
IB	2	0	0	0,1	21.5	70	77	38
IIA	1, 2	1	0	0,1	15.8	52	67	33
IIB	3	0-2	0	0,1	4.7	34	42	58
IIIA	4	0-2	0	0	4.7	37	45	62
IIIB	4	0-2	0	1	3.4	25	45	73
IVA1	1-4	0-2	0	2	3.8	18	20	83
IVA2	1-4	3	0	0-2	2.1	15	20	80
IVB	1-4	0-3	1	0-2	1.4	18 (5 year)	18 (5 year)	82 (5 year)

OS, overall survival; DSS, disease-specific survival; RDP, risk of disease progression