**The prognostic value of Serum CD163, TARC, and 𝛽2Microglobulin as response biomarkers in Hodgkin's lymphoma**

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**Abstract: Background:** Precise diagnosis and prediction of the prognosis is crucial for determining the optimal treatment strategy for Hodgkin's lymphoma (HL). This study aimed to investigate the prognostic utility of serum TARC, CD163 and Serum 𝛽2MG in HL. **Methods:** a multicenter prospective observational study was conducted on 84 patients with HL. Serum TARC and CD163 were quantified using ELISA techniques, while 𝛽2MG was assessed using radioimmunoassay. **Results:** Among the included patients, 32 were with advanced stages and 23 were treated with ABVD only. There were significant differences between either early and advanced stages or partial and complete disease response regarding the baseline of these three biomarkers (*P*<0.05). The ROC analysis showed that TARC, CD163, and 𝛽2MG had high diagnostic values in highlighting the advanced stages (AUC=0.84; *P*<0.001, AUC=0.79; *P*<0.001, and AUC=0.78; *P*<0.001, respectively). TARC showed the highest specificity, while 𝛽2MG showed the highest sensitivity. The Kaplan-Meier analysis showed that 𝛽2MG, CD163, and TARC were associated with good prognostic function and disease response prediction. **Conclusion:** Serum TARC and CD163 are good prognostic biomarkers for follow up of HL. Serial TARC, CD163, or 𝛽2MG measurements accurately reflected disease activity and response. Furthermore, the levels of TARC, CD163, and 𝛽2MG were reported to be highly associated with the disease severity.

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**Keywords:** TARC, CD163, 𝛽2MG, Hodgkin's lymphoma.

**1. Introduction**

Hodgkin’s Lymphoma (HL) is a chronic, progressive, neoplastic disorder associated with uncontrolled inflammatory response of the lymphatic tissue. Primarily, it affects lymph nodes, but it may progress to extra lymphatic sites as liver, spleen and bone marrow(1). Importantly, HL is one of the most curable malignancies with high survival rates(2). According to the Surveillance, Epidemiology, and End Results (SEER) Program, the 5-year survival rate has been on a continuous rise during the past ten years, reaching more than 90% in early stages and more than 80% in the advanced stages(3, 4). Nevertheless, a minority of cases does not optimally respond to the first line chemotherapeutic agents, exposing them to the unnecessary long-term toxicity(5). Consequently, the main focus of the current clinical research is to early define the refractory cases through more applicable prognostic tools. It has been reported that combined Computed Tomography with Positron Emission Tomography (CT/PET) scan is the currently used tool to determine chemosensitivity and assess treatment efficacy(6, 7). However, CT/PET is not the ideal tool. It has a poor positive predictive value, costly, and not easily applicable to do in each follow-up visit. In addition, it lacks accuracy, as interpretation may be influenced by a synchronous inflammation or infection(8). Moreover, detection of tissue biomarkers carries prognostic information but it is not the ideal tool for monitoring disease response and treatment efficacy(9). Blood-based biomarkers may carry hope, being much more practical, highly tolerable and economic. Nevertheless, blood-based biomarkers must have high specificity and sensitivity, at least comparable to the currently-used imaging method. The serum level of beta-2 microglobulin (𝛽2MG), a protein that present on the surface of nearly all nucleated cells, was reported to be useful in the prognosis of several lymphoid malignancies (10-12). It was reported to have favorable prognostic value in HL, especially in the advanced classic HL (13-15), thus it is used routinely as a biomarker for HL in our clinical practice. However, there is a controversy regarding its independence in the prognosis and monitoring the disease response(15).

Having the classic HL, the non-neoplastic tumor-infiltrating microenvironment accounts for the majority of the tumor mass, whilst the malignant Hodgkin –Reed–Sternberg (HRS) cells are minimal(16). Each of the malignant and non-malignant cells secrete biomarkers, but it is still controversial to determine whether type of biomarkers could be the best monitoring tool of disease response and treatment efficacy. It has been reported that HRS related chemokines carry more specificity, whilst those related to the microenvironment are more sensitive(5). The cysteine-cysteine chemokine ligand 17 (CCL 17), also named as thymus and activation regulated chemokine (TARC) is a specific biomarker to HRS cells. Therefore, TARC shows high specificity to HL patients. In addition, serial estimation of serum TARC levels can early determine the response to treatment, even after the first chemotherapeutic cycle(17-19). Furthermore, the anti-inflammatory M2 macrophages express the biomarker CD163. CD163 is reported to be elevated within the neoplastic node and in the serum of HL patients. Nevertheless, there is a paucity of clinical studies that evaluate CD163 for monitoring the disease response to treatment(20-23). Our study aims to investigate the prognostic utility of serum TARC, CD163 and Serum 𝛽2MG in patients with HL during and post therapy and measure the treatment response.

**2. Methods**

**Patients**

In this multicenter prospective observational study, we included 84 patients with HL from November 2015 till April 2016. The included patients aged from 18 to 70 years, with recently diagnosed HL and were not involved in any chemotherapeutic treatment program. We omitted patients who were positive for Epstein–Barr virus (EBV), HIV, active hepatitis B or C, or auto-immune disease. Furthermore, we omitted patients with previous history of malignancy, previous treatment with immunosuppressive agents, or previous history of immunosuppression. The initial staging was conducted based on PET and CT scans. The included patients were treated by either AVBD (adryamicin bleomycin, vinblastine, and dacarbazine) alone or combined with either other chemotherapeutic agents (BEACOPP, DHAP, IGEV, and MINE) or involved-field radiotherapy (IFRT) based on the stage of the disease according to the institutional guidelines. From the included patients, five serial blood samples were taken; immediately pretreatment, after the second cycle, after the third cycle, one month after treatment, and six months after treatment. The complete response and partial response of the disease were defined according to the International Harmonization response criteria or the International Working Group response criteria (24, 25). All participants signed informed consents at the beginning of the study.

**Serum biomarkers assay**

Under complete aseptic condition, 5 ml of peripheral venous blood was collected from each patient. The serum was stored at -80˚c until the completion of sample processing. Double-antibody sandwich ELISA was used for quantifying the serum level of both TARC and CD163. sTARC was quantified using the Human TARC ELISA kits (Ray Biotech, Inc., Norcross, Georgia) while sCD163 was quantified using Quantikine Human CD163 ELISA kits (R&D Systems, Inc., Minneapolis, MN). Each biomarker was assessed according to the manufacturer’s instructions. sCD163 was diluted into 1:20. On the other hand, 𝛽2MG was quantified using radioimmunoassay kit (Immunotech, Inc., Prague, Czech Republic) according to the manufacturer’s instructions. In order to ensure the accuracy, double assessment was performed and the average was obtained.

**Statistical analysis**

All statistical analyses of the data were done by statistical package for the social sciences (SPSS), version 20.0 for Windows (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed asmean ± SD, whereas categorical variables were expressed as numbers (percentages). A value of P < 0.05 was considered statistically significant. The main end point was the identification of patients with HL. The levels of markers were analyzed by analysis of variance (T-Test) but Chi-square test was done for independent samples. Overall Survival (OS) was defined as the time from diagnosis to death from any cause, or to time of last follow-up for patients who remained alive. The receiver operating characteristic (ROC) curve and area under curve (AUC) analysis was used to determine the sensitivity and specificity of each biomarker with the appropriate cutoff value. Furthermore, Kaplan–Meier analysis was used to estimate the OS.

**3. Results**

**Patients characteristics**

Among the included 84 patients with HL, the female to male ratio was 3:4, while the young (≤ 35 years) to older (> 35 years) patient ratio was 17: 25. The most frequent pathological subtype was nodular sclerosis, in 45 patients (53.5 %), followed by mixed cellularity that reportedin 23 patients (27.3%). However, lymphocyte depletion was reported in 10 patients (9.5 %) and nodular lymphocyte predominan twas reported in six patients (7.1 %). There were 52 patients (61.9 %) in the early stages (I, II) while 32 patients (38.1 %) were in the advanced stages (III, IV). Having the treatment, ABVD was the only treatment in 23 (38.1%) patients with 2-8 cycles. Combined ABVD with other chemotherapeutic options was the treatment in 42 (50%) patients, while combined ABVD with IFRT was used only with 10 patients. The disease response was complete in 34 (40.4 %) and partial in 48 (57.1 %) patients (Table1).

**Table 1. Clinicopathological characteristic of patients.**

|  |  |  |  |
| --- | --- | --- | --- |
| Clinical features | | No | Percent |
| Number of the included patients | | 84 | 100% |
| Sex (male) | | 48 | 57.2 % |
| Age (>35 years) | | 50 | 59.5% |
| stages | |  |  |
|  | I | 38 | 45.2% |
| II | 14 | 16.7% |
| III | 28 | 33.3% |
| IV | 4 | 4.8% |
| pathology | |  |  |
|  | Nodular sclerosis | 45 | (53.5%) |
| Mixed Cellularity | 23 | (27.3%) |
| Lymphocyte Depletion | 10 | (9.5%) |
| Nodular LymphocytePredominant | 6 | (7.1%) |
| B-Symptoms | | 22 | 26.2 % |
| Disease response | |  |  |
|  | Partial response | 48 | 57.1 % |
| complete response | 34 | 40.4 % |
| Therapy type | | | |
| ABVD only | | | |
|  | 2 cycles | 4 | 12.5% |
| 4 cycles | 8 | 25.0% |
| 6 cycles | 12 | 37.5% |
| 8 cycles | 8 | 25.0% |
| Total | 32 | 38.1% |
| ABVD and/or other chemotherapy | | 42 | 50.0% |
| ABVD+RT | | 10 | 11.9% |

Abbreviation, ABVD, adriamycin/bleomycin/vinblastine/dacarbazine; BEACOPP,bleomycin / etoposide / adriamycincyclophosphamide / vincristine / procarbazine / prednisone: DHAP,dexamethasone / highdoseara C / cisplatin; ICE,ifosfamide / carboplatin / etoposide;IGEV,ifosfamide / gemcitabine / vinorelbine / dexamethasone; MINE,mesna, ifosfamide, mitoxantrone, and etoposide; RT,radiotherapy.

**Table 2. Deference between biomarkers regarding the clinicopathological characteristics of the patients.**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 𝛽2MG | | | TARC | | | CD163 | | | variable | |
| P value | SD | mean | P value | SD | mean | P value | SD | mean |
|  |  |  |  |  |  |  |  |  | Pathology | |
| < 0.05 | 0.74 | 2.37 | < 0.05 | 75.30 | 263.38 | < 0.05 | 1.02 | 3.55 | Nodular Sclerosis |  |
| 0.39 | 2.68 | 78.21 | 257.04 | 1.20 | 3.82 | Mixed Cellularity |
| 0.27 | 2.03 | 69.71 | 235.30 | 1.18 | 3.79 | Lymphocyte Depletion |
| 0.61 | 1.98 | 68.92 | 204.13 | 1.04 | 3.33 | Nodular Lymphocyte Predominant |
|  |  |  |  |  |  |  |  |  | Ann prop stage | |
| <0.001 | 0.52 | 2.00 | <0.0001 | 65.83 | 206.61 | <0.001 | 1.00 | 3.25 | Early (I – II) |  |
| 0.92 | 3.19 | 84.88 | 322.97 | 1.30 | 4.77 | Advanced (III-VI) |
|  |  |  |  |  |  |  |  |  | Symptoms | |
| <0.05 | 1.16 | 3.83 | <0.001 | 103.84 | 318.96 | <0.01 | 1.09 | 4.87 | B-Symptoms |  |
| 0.77 | 2.79 | 69.20 | 219.68 | 1.10 | 3.88 | No-symptoms |
|  |  |  |  |  |  |  |  |  | Response | |
| <0.01 | 1.02 | 3.47 | <0.01 | 92.34 | 293.01 | <0.05 | 1.21 | 4.83 | Partial response |  |
| 0.62 | 2.13 | 71.12 | 229.63 | 1.11 | 3.51 | Complete response |
| CD163, cluster differentiation 163; TARC, Thymus and activation-regulated chemokine; 𝛽2MG, Beta 2 microglobulin | | | | | | | | | | |



**Figure 1. Receiver operating characteristics curve (ROC) and area under the curve (AUC) highlighting the diagnostic performance (sensitivity and specificity) of TARC, CD163, and 𝛽2MG in determining the disease severity in the form of; late stages (a) or presence of B symptoms (b).**



**Figure 2. Kaplan–Meier curves for estimation of over survival (OS) in patients of Hodgkin lymphoma; a, OS with serum 𝛽2M concentrations < 2.5 mg/l and >2.5 mg/l at prognosis; b, OS with serum CD163 concentrations<5.0 ng/ml and >5.0 ng/ml at prognosis; c, OS with serum TARC concentrations < 150 ng/l and >150 ng/l at prognosis; d, OS regarding the presence of B symptoms at the diagnosis.**

**Severity determination**

Having the pathology, there were significant differences between nodular sclerosis, mixed cellularity, lymphocyte depletion, and nodular lymphocyte predominant regarding the level of TARC, CD163, or 𝛽2MG at the baseline (*P*< 0.05 in all). Similarly, there was a high significant difference between early and advanced stages regarding the baseline of these three biomarkers (*P*<0.001 in all). Furthermore, the levels of these biomarkers were significantly higher in patients with B symptoms than patients without B symptoms (*P*< 0.05 in all). Moreover, the partial disease response was associated with higher values of these three biomarkers than the complete disease response (*P*< 0.05 in all) (Table 2).

The ROC analysis also showed that TARC, CD163, and 𝛽2MG had high diagnostic values in highlighting the advanced stages (AUC = 0.84; *P* value <0.001, AUC = 0.79; p value <0.001, and AUC = 0.78; p value <0.001, respectively). TARC showed the highest specificity (80.8%) followed by 𝛽2MG (76.9%) then CD163 (70.0%), while 𝛽2MGshowed the highest sensitivity (75.0%) followed by TARC (68.8%) then CD163 (62.5%). The optimal cutoff value for TARC was 150 ng/l that yield 77.8% sensitivity and 72.4% specificity. Regarding the CD163, the optimal cutoff value was 5.0 ng/ml that yield 76.7% sensitivity and 70.0% specificity. Similarly, 𝛽2MG displayed 66.7% sensitivity and 72.4% specificity with 2.50 mg/l as optima cutoff value (Figure 1).

**Assessment of the disease response**

The Kaplan Meier analysis showed that 𝛽2MGwas associated with best survival function as patients with 𝛽2MG<2.5 mg/l were more prone to favored disease response than patients with𝛽2MG<2.5 mg/l (*P*<0.001). Similarly, CD163 has shown good prognostic function and disease response prediction. Patients with CD163 <5.0 ng/ml were more prone to disease response than patients with CD163>5.0 ng/ml (*P*<0.001). Furthermore, TARC was associated with best survival function as patients with TARC <150 ng/l were more prone to favored response than patients with TARC>150 ng/l (*P*<0.04). Interestingly, presence of B symptoms can also predict the prognosis of and the disease response as absence of B symptoms was associated with better survival than presence of B symptoms (Figure 2).

**4. Discussion**

Precise diagnosis and meticulous prediction of the prognosis of each patient with HL is crucial for determining the optimal treatment strategy. Our study revealed that serum TARC, CD163 and Serum 𝛽2MGare of high diagnostic and prognostic values through predicting the severity and disease response. The HRS cell specific TARC is a highly specific biomarker for disease activity (26, 27). In about 85% of patients, TARC is detectable and elevated in the serum at the diagnosis and before the treatment. Previous studies also showed that the pre-treatment serum TARC levels significantly correlated with stages of the disease, metabolic activity, and erythrocyte sedimentation rate (18). Moreover, any changes in TARC levels during chemotherapy may be a biomarker for treatment response evaluation (28). These results, in addition to the results of Plattel et al(29), support the accuracy of TARC in predicting the severity of the disease and the treatment response. Therefore, TARC may be used as a cancer-specific serum biomarker for defining diagnosis and prognosis of HL. Moreover, there is an increasing interest on the amount of tumor associated macrophages (TAM) infiltration in the tumor microenvironment. The amount of TAM is strongly associated with not only shortened survival but also the likelihood of relapse for disease-specific survival(22). The functional characterization of TAM is still to be performed. Possibly, differences in survival among patients could be explained by the macrophages M1/M2 binary, on which these cells differentiate. Furthermore, the M2 macrophage marker soluble CD163 is elevated in serum of patients with HL(28, 30). Unlike M1 macrophages, M2 macrophages prompt tumor cell growth and metastasis (31). CD163 is currently investigated as an additional biomarker of macrophage infiltration in HL microenvironment and its increased level is associated with poor outcome, and a rise in the treatment-related deaths with poor survival rate (23). Recently, the circulating fraction of CD163 in serum has been evaluated in patients at diagnosis and relapse, showing that it is not inferior to TARC to identify patients with poor outcome. Moreover, several studies demonstrated that elevated CD163 expression correlates with advanced cancer stages, unfavorable prognosis, early distant recurrence, and reduced patient survival in various types of cancers, including HL(32).

Noticeably, CD163 not only exists as a membrane-bound form, but also presents as a soluble form in plasma and other tissue fluids. The M2 macrophage soluble CD163 is elevated in serum of patients with HL. Furthermore, serum CD163 has been reported to be elevated in several inflammatory conditions, such as sepsis, diabetes, liver cirrhosis, rheumatoid arthritis, human immunodeficiency virus and macrophage activation syndrome(33). Nevertheless, this does not explain the different patterns observed in plasma versus serum samples. Interestingly, a correlation has been found between CD163 and interim response. It is worthy that complete remission and partial remission are greatly overlapped. Jones et al showed a gradual decrease of sCD163 during and after treatment in serum samples of classical HL patients(28). We observed a similar pattern in our serum samples, while the plasma samples showed a slight post-treatment rise in soluble CD163 levels. This increase might reflect treatment-induced inflammatory responses. This makes CD163 less useful as a biomarker for response evaluation at the individual patient level(28). However, our study revealed that soluble CD163 level was significantly correlated with disease severity and response to treatment. Our results are supported by the results of Plattel et al who reported a significant correlation between CD163 and the presence of B symptoms (29).

On the other hands, the initial level of 𝛽2MG has been also confirmed to be an important diagnostic biomarker in most lympho-proliferative diseases in adults, including HL. Our results support the previous results revealing high correlation between serum 𝛽2MGand either Ann Arbor stage, the presence of B symptoms, or unfavorable prognosis (34). In accordance with our results, Nakajima et al demonstrated that the ROC curve analysis showed that the appropriate cutoff of serum 𝛽2MG levels is 2.5 mg/L for predicting the overall survival. It is also estimated that serum 𝛽2MG had a tendency to be significantly associated with age more than 45 years and Ann Arbor stages III–IV(35). By virtue of such biomarkers, HL has changed its prognosis from being relatively incurable to one in which patients have a high likelihood of long-term survival (36).

In patients with advanced-stage HL, the early response after two courses of ABVD chemotherapy, when evaluated with 18 FDG-PET scan, showed important prognostic significance (37). It has been reported that the complete response has a rate of 73-89%, whilst the 5-year freedom from progression rate is 73-76%. In addition, the 5-year overall survival rate reached up to 90% in intermediate and advanced stage HL(38).

**5. Conclusion**

Our study showed that serum TARC and CD163 may serve as good prognostic biomarkers for follow up of HL, particularly in the absence of B symptoms. Serial TARC measurements accurately reflected disease activity and correlated with clinical treatment response at the individual patient level. Moreover, CD163 was found to be elevated in HL patients. Furthermore, the levels of TARC, CD163, and 𝛽2MG were reported to be highly associated with the disease severity. The combination of CD163, TARC, and𝛽2MG may significantly improve the prognostic value of HL than that of 𝛽2MG alone. Therefore, further studies investigating the roles of the combination of these three biomarkers in both diagnosis and prognosis are needed.

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**References**

1. Lister TA, Crowther D, Sutcliffe SB, Glatstein E, Canellos GP, Young RC, et al. Report of a committee convened to discuss the evaluation and staging of patients with Hodgkin's disease: Cotswolds meeting. Journal of Clinical Oncology. 1989;7(11):1630-6.
2. Maselli D, Pizio R, Musumeci F. Multifrequency transcranial Doppler for intraoperative automatic detection and characterisation of cerebral microemboli during port-access mitral valve surgery. Interactive cardiovascular and thoracic surgery. 2006;5(1):32-5.
3. Brenner H, Gondos A, Pulte D. Ongoing improvement in long-term survival of patients with Hodgkin disease at all ages and recent catch-up of older patients. Blood. 2008;111(6):2977-83.
4. Brenner H, Gondos A, Pulte D. Survival expectations of patients diagnosed with Hodgkin's lymphoma in 2006–2010. The oncologist. 2009;14(8):806-13.
5. Jones KL, Vari F, Keane C, Crooks P, Nourse JP, Seymour LA, et al. Serum CD163 and TARC as disease response biomarkers in classical Hodgkin lymphoma. Clinical cancer research. 2012: clincanres.-2693.012.
6. Barnes JA, LaCasce AS, Zukotynski K, Israel D, Feng Y, Neuberg D, et al. End-of-treatment but not interim PET scan predicts outcome in nonbulky limited-stage Hodgkin’s lymphoma. Annals of oncology. 2010;22(4):910-5.
7. Hutchings M, Mikhaeel NG, Fields PA, Nunan T, Timothy AR. Prognostic value of interim FDG-PET after two or three cycles of chemotherapy in Hodgkin lymphoma. Annals of oncology. 2005;16(7):1160-8.
8. Jones K, Gandhi MK. Can a blood test monitor lymphoma? Leukemia & lymphoma. 2010;51(6):957-9.
9. Garcıa JF, Camacho FI, Morente M, Fraga M, Montalbán C, Álvaro T, et al. Hodgkin and Reed-Sternberg cells harbor alterations in the major tumor suppressor pathways and cell-cycle checkpoints: analyses using tissue microarrays. Blood. 2003;101(2):681-9.
10. Federico M, Guglielmi C, Luminari S, Mammi C, Marcheselli L, Gianelli U, et al. Prognostic relevance of serum β2 microglobulin in patients with follicular lymphoma treated with anthracycline-containing regimens. A GISL study. haematologica. 2007;92(11):1482-8.
11. Li Z-M, Zhu Y-J, Sun J, Xia Y, Huang J-J, Zou B-Y, et al. Serum beta2-microglobin is a predictor of prognosis in patients with upper aerodigestive tract NK/T-cell lymphoma. Annals of hematology. 2012;91(8):1265-70.
12. Miyashita K, Tomita N, Taguri M, Suzuki T, Ishiyama Y, Ishii Y, et al. Beta-2 microglobulin is a strong prognostic factor in patients with DLBCL receiving R-CHOP therapy. Leukemia research. 2015;39(11):1187-91.
13. Chronowski GM, Wilder RB, Tucker SL, Ha CS, Sarris AH, Hagemeister FB, et al. An elevated serum beta‐2‐microglobulin level is an adverse prognostic factor for overall survival in patients with early‐stage Hodgkin disease. Cancer. 2002;95(12):2534-8.
14. Vassilakopoulos TP, Nadali G, Angelopoulou MK, Siakantaris MP, Dimopoulou MN, Kontopidou FN, et al. The prognostic significance of beta (2)-microglobulin in patients with Hodgkin's lymphoma. haematologica. 2002;87(7):701-8.
15. Wang Q, Qin Y, Zhou S, He X, Yang J, Kang S, et al. Prognostic value of pretreatment serum beta-2 microglobulin level in advanced classical Hodgkin lymphoma treated in the modern era. Oncotarget. 2016;7(44):72219.
16. Gandhi MK, Lambley E, Duraiswamy J, Dua U, Smith C, Elliott S, et al. Expression of LAG-3 by tumor-infiltrating lymphocytes is coincident with the suppression of latent membrane antigen–specific CD8+ T-cell function in Hodgkin lymphoma patients. Blood. 2006;108(7):2280-9.
17. Ma Y, Visser L, Roelofsen H, de Vries M, Diepstra A, van Imhoff G, et al. Proteomics analysis of Hodgkin lymphoma: identification of new players involved in the cross-talk between HRS cells and infiltrating lymphocytes. Blood. 2008;111(4):2339-46.
18. Niens M, Visser L, Nolte IM, Van Der Steege G, Diepstra A, Cordano P, et al. Serum chemokine levels in Hodgkin lymphoma patients: highly increased levels of CCL17 and CCL22. British journal of haematology. 2008;140(5):527-36.
19. Weihrauch MR, Manzke O, Beyer M, Haverkamp H, Diehl V, Bohlen H, et al. Elevated serum levels of CC thymus and activation-related chemokine (TARC) in primary Hodgkin's disease: potential for a prognostic factor. Cancer research. 2005;65(13):5516-9.
20. Barros MHM, Hassan R, Niedobitek G. Tumor-associated macrophages in pediatric classical Hodgkin lymphoma: association with Epstein-Barr virus, lymphocyte subsets, and prognostic impact. Clinical cancer research. 2012;18(14):3762-71.
21. Sánchez-Espiridión B, Martin-Moreno AM, Montalbán C, Medeiros LJ, Vega F, Younes A, et al. Immunohistochemical markers for tumor associated macrophages and survival in advanced classical Hodgkin’s lymphoma. Haematologica. 2012;97(7):1080-4.
22. Steidl C, Lee T, Shah SP, Farinha P, Han G, Nayar T, et al. Tumor-associated macrophages and survival in classic Hodgkin's lymphoma. New England Journal of Medicine. 2010;362(10):875-85.
23. Yoon DH, Koh YW, Kang HJ, Kim S, Park C-S, Lee S-w, et al. CD68 and CD163 as prognostic factors for Korean patients with Hodgkin lymphoma. European journal of haematology. 2012;88(4):292-305.
24. Cheson BD, Horning SJ, Coiffier B, Shipp MA, Fisher RI, Connors JM, et al. Report of an international workshop to standardize response criteria for non-Hodgkin's lymphomas. Journal of clinical oncology. 1999;17(4):1244-.
25. Cheson BD, Pfistner B, Juweid ME, Gascoyne RD, Specht L, Horning SJ, et al. Revised response criteria for malignant lymphoma. Journal of clinical oncology. 2007;25(5):579.
26. Moskowitz AJ, Cho S, Fleisher M, Woo KM, Zhang Z, Fox S, et al. TARC predicts PET-normalization and event free surival in relapsed/refractory Hodgkin lymphoma patients treated with brentuximab vedotin: Am Soc Hematology; 2015 2015.
27. Sauer M, Plütschow A, Jachimowicz RD, Kleefisch D, Reiners KS, Ponader S, et al. Baseline serum TARC levels predict therapy outcome in patients with Hodgkin lymphoma. American journal of hematology. 2013;88(2):113-5.
28. Jones K, Nourse JP, Keane C, Bhatnagar A, Gandhi MK. Plasma microRNA are disease response biomarkers in classical Hodgkin lymphoma. Clinical cancer research. 2013.
29. Plattel WJ, Alsada ZND, Imhoff GW, Diepstra A, Berg A, Visser L. Biomarkers for evaluation of treatment response in classical Hodgkin lymphoma: comparison of sGalectin-1, sCD163 and sCD30 with TARC. British journal of haematology. 2016;175(5):868-75.
30. Ouyang J, Plütschow A, von Strandmann EP, Reiners KS, Ponader S, Rabinovich GA, et al. Galectin-1 serum levels reflect tumor burden and adverse clinical features in classical Hodgkin lymphoma. Blood. 2013;121(17):3431-3.
31. Jensen TO, Schmidt H, Møller HJ, Høyer M, Maniecki MB, Sjoegren P, et al. Macrophage markers in serum and tumor have prognostic impact in American Joint Committee on Cancer stage I/II melanoma. Journal of clinical oncology. 2009;27(20):3330-7.
32. Komohara Y, Niino D, Saito Y, Ohnishi K, Horlad H, Ohshima K, et al. Clinical significance of CD163+ tumor-associated macrophages in patients with adult T-cell leukemia/lymphoma. Cancer science. 2013;104(7):945-51.
33. Etzerodt A, Moestrup SK. CD163 and inflammation: biological, diagnostic, and therapeutic aspects. Antioxidants & redox signaling. 2013;18(17):2352-63.
34. Dimopoulos MA, Cabanillas F, Lee JJ, Swan F, Fuller L, Allen PK, et al. Prognostic role of serum beta 2-microglobulin in Hodgkin's disease. Journal of clinical oncology. 1993;11(6):1108-11.
35. Nakajima Y, Tomita N, Watanabe R, Ishiyama Y, Yamamoto E, Ishibashi D, et al. Prognostic significance of serum beta-2 microglobulin level in Hodgkin lymphoma treated with ABVD-based therapy. Medical Oncology. 2014;31(9):185.
36. Hodgson DC, Gilbert ES, Dores GM, Schonfeld SJ, Lynch CF, Storm H, et al. Long-term solid cancer risk among 5-year survivors of Hodgkin's lymphoma. Journal of Clinical Oncology. 2007;25(12):1489-97.
37. Terasawa T, Lau J, Bardet S, Couturier O, Hotta T, Hutchings M, et al. Fluorine-18-fluorodeoxyglucose positron emission tomography for interim response assessment of advanced-stage Hodgkin's lymphoma and diffuse large B-cell lymphoma: a systematic review. Journal of Clinical Oncology. 2009;27(11):1906-14.
38. Gordon LI, Hong F, Fisher RI, Bartlett NL, Connors JM, Gascoyne RD, et al. Randomized phase III trial of ABVD versus Stanford V with or without radiation therapy in locally extensive and advanced-stage Hodgkin lymphoma: an intergroup study coordinated by the Eastern Cooperative Oncology Group (E2496). Journal of Clinical Oncology. 2013;31(6):684.

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