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ORIGINAL ARTICLE – CLINICAL ONCOLOGY

# The role of autologous stem cell transplantation in peripheral T cell lymphoma: a long-term follow-up single-center experience

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## Abstract

**Purpose** Peripheral T cell lymphomas (PTCL) are a rare and heterogeneous group of aggressive non-Hodgkin lymphomas, showing a generally poor prognosis. In this retrospective analysis, we aimed to investigate the impact of autologous stem cell transplantation (autoSCT) in PTCL.

**Methods** A retrospective analysis of 58 consecutive unselected PTCL patients aged 21–71 years undergoing autoSCT as first-line consolidation as well as in the relapse setting was performed.

**Results** The median follow-up time was 67 months. A 5-year overall survival (OS) of 53% and a 5-year progression-free survival (PFS) after autoSCT of 44% was achieved. The overall relapse rate after autoSCT was 50%. On multivariate analysis, standard baseline characteristics such as age, disease stage and international prognostic index (IPI) score failed to predict outcome in our cohort. First-line treatment with autoSCT was not associated with a benefit in OS when compared to patients receiving autoSCT at relapse. Notably, autoSCT seemed to be a suitable approach even for older transplant-eligible patients (aged ≥ 60 years), with a similar 5-year OS of 49% when compared to younger patients.

**Conclusions** Our study suggests that autoSCT can achieve long-term survival in PTCL patients even after relapse and should also be considered for eligible older patients.

**Keywords** PTCL · T cell lymphoma · Non-Hodgkin lymphoma · Autologous stem cell transplantation · AutoSCT

## Introduction

Peripheral T cell lymphomas (PTCL) comprise a heterogenous group of non-Hodgkin lymphomas that are associated with a considerably poorer outcome when compared to their B cell counterparts (Coiffier et al. 1990; Foss et al. 2011; Project IT-CL 2008). Establishing a standard of care for patients with PTCL is difficult, given the rarity of the disease and the resulting paucity of comparative trials (Moskowitz et al. 2014). During the past decades, induction treatment with CHO(E)P (cyclophosphamide, doxorubicin, vincristine, etoposide, prednisone) followed by high-dose chemotherapy and autologous stem cell transplantation (autoSCT) has often been practiced as a standard treatment for transplant eligible patients (d'Amore et al. 2015; Kharfan-Dabaja et al. 2017; Moskowitz et al. 2014). Nevertheless, despite several studies approaching this issue, the status of first-line autoSCT has not been settled (Foss et al. 2011; Gkotzamanidou and Papadimitriou 2014; Moskowitz et al. 2014). In fact, autoSCT as first-line consolidation therapy has been questioned again by recent reports, where no survival benefit was seen in respective patients (Fossard et al. 2017; Rohlfing et al. 2018). To identify patients with a high risk for relapse, who might gain a particular benefit from up-front treatment intensification, a number of prognostic scores have been evaluated in PTCL (Gutiérrez-García et al. 2010; Piccaluga et al. 2010). While some scores, such as the adopted

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international prognostic index (IPI) or the prognostic index for T cell lymphomas (PIT) have demonstrated some usefulness, they repeatedly showed only little prognostic value in subsequent reports (d'Amore et al. 2012; Gutiérrez-García et al. 2010; Piccaluga et al. 2010; Rohlfing et al. 2018). Of note, varying factors were associated with outcome in different patient cohorts, further emphasizing the heterogeneity of PTCL (Corradini et al. 2006; d'Amore et al. 2012; Fossard et al. 2017; Rohlfing et al. 2018). While CHO(E)P is generally accepted as standard induction regimen, the role of a defined mobilization regimen prior to stem cell harvest has not been addressed in PTCL patients (Corradini et al. 2006; d'Amore et al. 2012; Moskowitz et al. 2014). By including cytostatic agents different from induction therapy, these regimens might add to achieving optimal remission in the frontline setting. Nevertheless, peripheral stem cell harvest is usually performed following a regular induction cycle (d'Amore et al. 2012; Moskowitz et al. 2014). In this retrospective analysis, we give insight into a single-center experience regarding the treatment of 58 consecutive patients with PTCL who underwent autoSCT, either as first-line consolidation therapy or in the relapse setting and performed a multivariant analysis with the aim to determine predictive baseline characteristics.

## Materials and methods

### Patients, data collection and response assessment

For this retrospective analysis, we identified consecutive patients diagnosed with ALK± ALCL (anaplastic lymphoma kinase positive/negative anaplastic large cell lymphoma), PTCL-NOS (PTCL not otherwise specified), AITL (angioimmunoblastic T cell lymphoma), EATCL (enteropathy-associated T cell lymphoma) or NKTL (NK/T cell lymphoma), who received autoSCT at the Department of Hematology and Oncology, University Hospital Tübingen from 1998 to 2017. Histological diagnosis was made by an expert hematopathologist. The choice of treatment for induction and consolidation (up-front autoSCT or observation) was at the discretion of the treating physician. The response assessment was determined at the end of induction treatment based on the International Working Group (IWG) criteria (Cheson et al. 1999). Computed tomography (CT) was used to assess tumor response and was analyzed by local radiologists.

### Statistical analysis

For statistical analysis, GraphPad Prism 7.0 (GraphPad Software Inc., La Jolla, CA, USA) and JMP 12.0 (SAS Institute Inc., San Francisco, CA, USA) were used. Overall survival (OS) and progression-free survival (PFS) were calculated using the Kaplan–Meier estimate. OS was defined as time from diagnosis to death from any cause and PFS was defined as time from autoSCT to relapse, progression or death from any cause, whichever occurred first. If no event occurred, data were censored and the time from primary diagnosis or autoSCT until the last recorded patient contact was calculated, respectively. The log-rank test was used for the comparison of Kaplan–Meier estimates between different groups of patients with a significance level α of 0.05. The median follow-up time was assessed using a reverse Kaplan–Meier estimate (Schemper and Smith 1996). The Cox proportional hazards regression model was used to assess the effect of multiple variables on OS and PFS. All p values are two sided.

## Results

### Patient characteristics

Retrospective follow-up data were available for 58 consecutive PTCL patients aged between 21 and 71 years who underwent autologous stem cell transplantation at the Department of Oncology and Hematology at the University Hospital Tübingen from 1998 to 2017. 40 patients received up-front autoSCT, while 18 patients were treated with autoSCT at relapse. Patient characteristics for the two groups are shown in Table 1. Most common PTCL subtypes within our cohort were AITL (25.9%), followed by EATCL (22.4%), PTCL-NOS (20.7%) and ALK− ALCL (19.0%). Only 12% of PTCL patients presented with ALK+ ALCL or NKTL. The majority of patients (79.3%) presented with stage III or IV disease and 41.4% had a high-intermediate or high IPI (IPI ≥ 3) at diagnosis. Most patients received CHOP (51.7%) or CHOEP (22.4%) chemotherapy as induction treatment regimen. Less frequently used induction regimens were VACOP-B (etoposide, doxorubicin, cyclophosphamide, vincristine, prednisone, bleomycin) and methotrexate (MTX) containing regimens (in 10.3% and 12.1% of patients, respectively, Table 1). The median number of induction cycles was five (range 2–8), four (range 4–6) and six (range 4–6) in patients receiving CHOP, CHOEP and MTX-containing regimens, respectively. Patients treated for VACOP-B had a median of six weeks of therapy (range 6–8 weeks). Subsequently, DHAP (dexamethasone, high-dose cytarabine, cisplatin) or VIP-E (etoposide, ifosfamide, cisplatin, epirubicin (Brugger et al. 1992)) chemotherapy (each regimen 37.9% of patients) were most frequently used as stem cell mobilization therapy prior to peripheral blood stem cell harvest. 20.6% of patients received other mobilization regimens (10.3% VIP, 10.3% MTX containing regimens), in two patients peripheral blood stem cell harvest was performed after a regular induction

**Table 1** Patient characteristics

| Characteristic | AutoSCT up-front | AutoSCT relapse | Total |
|---|---|---|---|
| Patient | 40 | 18 | 58 |
| Age (years) | | | |
| Median | 56 | 59 | 56 |
| Range | 21–70 | 21–71 | 21–71 |
| Sex [no. (%)] | | | |
| Male | 12 (30.0) | 12 (66.7) | 24 (41.4) |
| Female | 28 (70.0) | 6 (33.3) | 34 (58.6) |
| PTCL subtype [no. (%)] | | | |
| AITL | 9 (22.5) | 6 (33.3) | 15 (25.9) |
| EATCL | 11 (27.5) | 2 (11.1) | 13 (22.4) |
| PTCL-NOS | 8 (20.0) | 4 (22.2) | 12 (20.7) |
| ALCL ALK− | 8 (20.0) | 3 (16.7) | 11 (19.0) |
| ALCL ALK+ | 2 (5.0) | 3 (16.7) | 5 (8.6) |
| NKT | 2 (5.0) | 0 (0.0) | 2 (3.4) |
| Stage [no. (%)] | | | |
| I/II | 7 (17.5) | 5 (27.8) | 12 (20.7) |
| III/IV | 33 (82.5) | 13 (72.2) | 46 (79.3) |
| B-symptoms [no. (%)] | 24 (60.0) | 11 (61.1) | 35 (60.3) |
| LDH [no. (%)] | | | |
| > Normal | 16 (40.0) | 7 (38.9) | 23 (39.7) |
| n.a. | 2 (5.0) | 3 (16.7) | 5 (8.6) |
| IPI [no. (%)] | | | |
| Low | 11 (27.5) | 7 (38.9) | 18 (31.0) |
| Low-intermediate | 11 (27.5) | 2 (11.1) | 12 (20.7) |
| High-intermediate | 8 (20.0) | 4 (22.2) | 12 (20.7) |
| High | 9 (22.5) | 3 (16.7) | 12 (20.7) |
| n.a. | 1 (2.5) | 2 (11.1) | 3 (5.2) |
| First-line treatment [no. (%)] | | | |
| CHOP | 18 (45.0) | 12 (66.7) | 30 (51.7) |
| CHOEP | 12 (30.0) | 1 (5.6) | 13 (22.4) |
| VACOP-B | 5 (12.5) | 1 (5.6) | 6 (10.3) |
| MTX containing | 5 (12.5) | 2 (11.1) | 7 (12.1) |
| Others | 0 (0.0) | 2 (11.1) | 2 (3.4) |
| Mobilization treatment [no. (%)] | | | |
| w/o Anthracycline | 19 (47.5) | 7 (38.9) | 26 (44.8) |
| Anthracycline containing | 21 (52.5) | 11 (61.1) | 32 (55.2) |
| High-dose regimen [no. (%)] | | | |
| BEAM | 39 (97.5) | 17 (94.4) | 56 (96.6) |
| Others | 1 (2.5) | 1 (5.6) | 2 (3.4) |
| Remission status prior to autoSCT [no. (%)] | | | |
| SD | 1 (2.5) | 0 (0.0) | 1 (1.7) |
| PR | 23 (57.5) | 8 (44.4) | 31 (53.4) |
| CR | 16 (40.0) | 10 (55.6) | 26 (44.8) |

*AITL* angioimmunoblastic T cell lymphoma, *EATCL* enteropathy-associated T cell lymphoma, *PTCL-NOS* peripheral T cell lymphoma not otherwise specified, *ALCL ALK±* anaplastic large cell lymphoma, anaplastic lymphoma kinase positive/negative, *NKT* NK/T cell lymphoma, *IPI* international prognostic index, *LDH* lactate dehydrogenase, *CHO(E)P* cyclophosphamide doxorubicin vincristine (etoposide) prednisone, *VACOP-B* etoposide doxorubicin cyclophosphamide vincristine prednisone bleomycin, *MTX* methotrexate, *BEAM* carmustine etoposide cytarabine melphalan, *SD* stable disease, *PR* partial remission, *CR* complete remission, *autoSCT* autologous stem cell transplant, *alloSCT* allogenic stem cell transplant

cycle. PBSCT harvest was successful, yielding sufficient CD34+ cells for autoSCT in all patients in our cohort (median CD34+ hematopoietic stem cell harvest $8.2 \times 10^6$ CD34+ cells/kg body weight (range 3.0–62.2), Supplementary Table S1). High-dose BEAM was the standard regimen before autoSCT in both settings and was administered in 56 of 58 patients (96.6%). Second line regimens for patients with relapse after conventional chemotherapy varied considerably. Again, DHAP and VIP-E were used most frequently (in 17/29 patients, 58.6%); brentuximab vedotin was administered in five patients (17.2%). Remission status was similar in both groups prior to autoSCT, with a complete remission (CR) in 44.8% and a partial remission (PR) in 53.4% of evaluated PTCL patients. Twelve patients in our cohort underwent alloSCT at relapse after autoSCT. One patient developed acute myeloid leukemia and, therefore, underwent alloSCT; three patients were treated with an auto/alloSCT concept (one patient as first-line therapy, two patients at relapse) (Fig. 1). All patients undergoing alloSCT in our cohort underwent myeloablative conditioning therapy. The most frequently used regimen was fludarabine/melphalan (in 50% of patients). Other patients received cyclophosphamide or fludarabine-based combination chemotherapy, which was combined with total body irradiation (TBI) in six of these patients (37.5%).

## Outcome and survival

Figure 1 summarizes the outcome after autoSCT in our PTCL cohort. The median follow-up time was 67 (range 13–153) months in the frontline autoSCT group and 163 (range 48–278) months in the relapse autoSCT group. Only 8.6% (5/58) patients had a follow-up time of less than one year. AutoSCT was generally well tolerated in both groups with no occurrence of transplant-related deaths and timely regeneration of hematopoiesis in all patients. Overall relapse rate after autoSCT regardless of the transplant setting was 50.0% with a 5-year progression-free survival (PFS) after autoSCT of 44.4% (median 37 months) and a 5-year overall survival (OS) of 53.3% (median 92 months) (Fig. 2a, b). Main cause of death was disease progression (19/31 patients, 61.3%). In the frontline autoSCT group ($n = 40$), the estimated 5-year progression-free survival (PFS) after autoSCT was 34.5% (median 26 months) and the

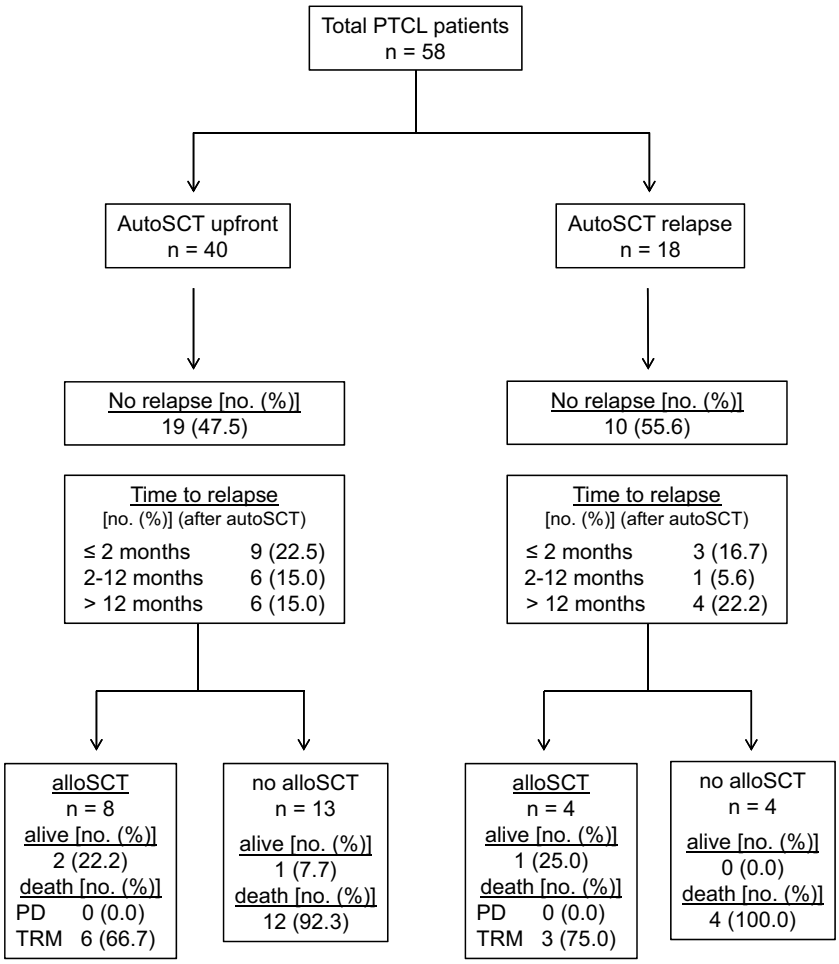


**Fig. 1** Flow diagram of treatment and outcome of all PTCL patients. Flow diagram regarding treatment and outcome of all peripheral T cell lymphoma (PTCL) patients treated with autoSCT up-front or at relapse at the University Hospital Tübingen from 1998 to 2017. *PTCL-NOS* peripheral T cell lymphoma not otherwise specified, *autoSCT* autologous stem cell transplant, *alloSCT* allogenic stem cell transplant, *PD* progressive disease, *TRM* transplant-related mortality

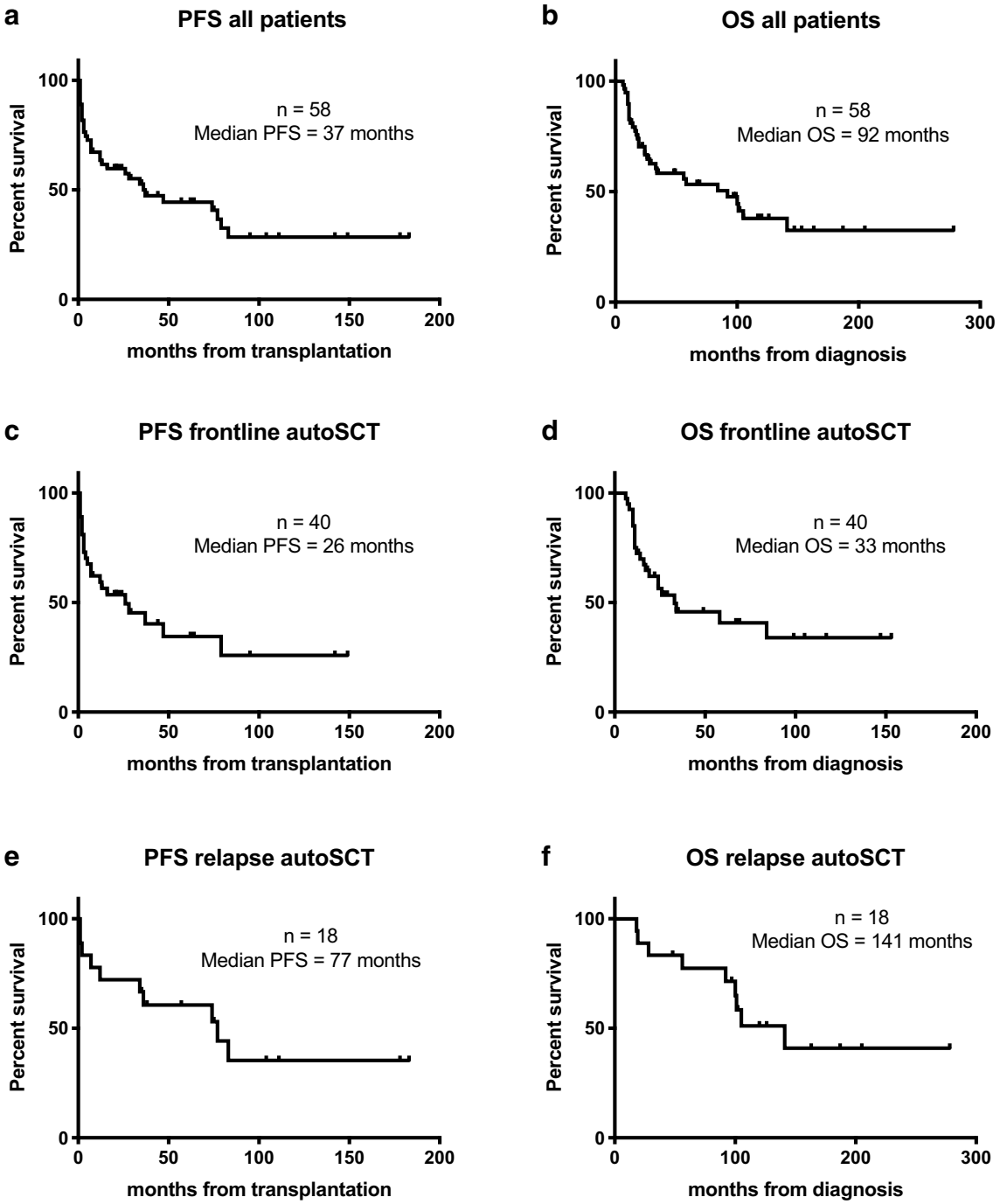


**Fig. 2** Overall survival and progression-free survival. Kaplan–Meier curves regarding progression-free and overall survival in all peripheral T cell lymphoma patients (**a**, **b**), patients treated with frontline autoSCT (**c**, **d**) and patients treated with autoSCT at relapse (**e**, **f**). *OS* overall survival, *PFS* progression-free survival

5-year overall survival (OS) was 40.7% (median 33 months) (Fig. 2c, d). Of note, the group of patients receiving autoSCT at first relapse ($n = 18$) showed a more favorable outcome with a 5-year PFS after autoSCT of 60.6% (median 77 months) and a 5-year OS of 77.4% (median 141 months) (Fig. 2e, f). Patients with the ALK− ALCL subtype showed a significantly longer time to progression when compared to the EATL subtype (median PFS "not reached" versus 13 months, $p = 0.01$). No significant differences were seen in overall survival between PTCL subtypes, although the AITL and ALK− ALCL subtypes were associated with a slightly better OS compared to EATL and PTCL-NOS

(Fig. 3a, b). Patient age ≥ 60 years was not associated with a significant difference in OS and PFS when compared to younger patients in our cohort (Fig. 3c, d). The estimated 5-year OS was 48.7% (median OS 58 months) in the ≥ 60 cohort ($n = 25$) and 56.5% (median OS 141 months) in the < 60 cohort ($n = 33$). Noteworthy, there was a very high transplant-related mortality (TRM) of 75.0% (9/12) in the twelve patients in our cohort undergoing allogenic stem cell transplantation (alloSCT) at relapse after autoSCT. The most common cause of death in this setting were infections (6/9), with five deaths due to infectious complications in the immediate context of alloSCT (range 2–25 days after transplantation). Other causes included graft versus host disease (1/9), heart failure (1/9) and intracranial bleeding (1/9). No patient experienced lymphoma relapse after alloSCT. Patients who relapsed after autoSCT and were not able to proceed to alloSCT had a median survival after relapse of only three months and all but one (16/17) of these patients had died at the time of assessment.

## Multivariate analysis

To evaluate the impact of baseline characteristics and the choice of treatment on the outcome in our heterogenous group of PTCL patients and diseases, a multivariate analysis was performed. Statistical analysis of the individually assessed factors regarding their correlation with OS and PFS is shown in Table 2. Of note, standard baseline characteristics such as age, disease stage and IPI failed to predict outcome in our PTCL cohort. As already mentioned, the ALK− ALCL subtype was associated with a significantly longer PFS (when compared to EATL), while no other significant differences in PFS or OS among PTCL subtypes were observed. The choice of mobilization treatment, in particular whether or not the regimen contained anthracyclines, did not correlate with outcome in our cohort. Although statistical significance was just missed, a longer time to autoSCT was associated with a better OS (HR 0.04) and PFS (HR 0.05) in our cohort.

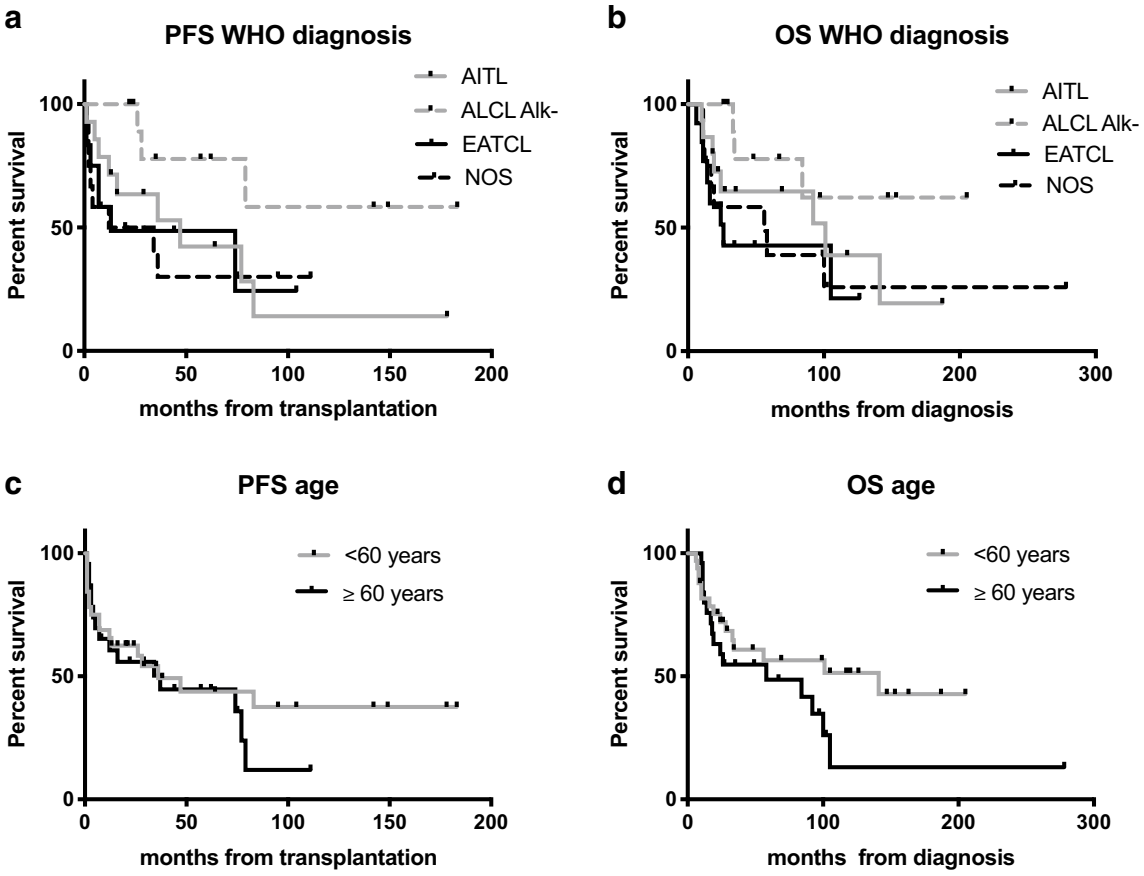


**Fig. 3** Overall survival and progression-free survival per subgroup. Kaplan–Meier curves regarding progression-free and overall survival in all peripheral T cell lymphoma patients divided into subgroups by histologic subtype (**a**, **b**) and age (≥ 60 years or younger, **c**, **d**). *OS* overall survival, *PFS* progression-free survival

**Table 2** Multivariate analysis

| Characteristic | OS | | PFS | |
|---|---|---|---|---|
| | *p* value | HR (95% CI) | *p* value | HR (95% CI) |
| Age | | | | |
| < 60 years (vs. ≥ 60 years) | 0.18 | 0.55 (0.21–1.33) | 0.16 | 0.56 (0.23–1.28) |
| Gender | | | | |
| Male (vs. female) | 0.54 | 1.38 (0.49–4.06) | 0.93 | 1.04 (0.42–2.64) |
| PTCL subtype | | | | |
| AITL (vs. EATCL) | 0.29 | 0.44 (0.10–2.02) | 0.54 | 0.63 (0.14–2.81) |
| NOS (vs. EATCL) | 0.55 | 0.66 (0.17–2.59) | 0.79 | 0.84 (0.22–3.16) |
| ALCL ALK− (vs. EATCL) | 0.08 | 0.24 (0.04–1.16) | 0.04 | 0.21 (0.04–0.96) |
| Stage | | | | |
| I/II vs. III/IV | 0.56 | 0.72 (0.23–2.09) | 0.57 | 0.75 (0.26–2.02) |
| IPI | | | | |
| Low/low-int. (vs. high-int./high) | 0.16 | 0.50 (0.18–1.31) | 0.28 | 0.60 (0.22–1.52) |
| Mobilization treatment | | | | |
| Antracycline cont. (vs. no antracycline cont.) | 0.69 | 1.38 (0.43–3.65) | 0.77 | 1.16 (0.44–3.29) |
| Remission status at autoSCT | | | | |
| CR (vs. no CR) | 0.70 | 1.21 (0.46–3.43) | 0.25 | 1.68 (0.70–4.35) |
| Time to autoSCT (per month) | 0.06 | 0.04 (0.0003–1.13) | 0.07 | 0.05 (0.002–1.26) |

*AITL* angioimmunoblastic T cell lymphoma, *EATCL* enteropathy-associated T cell lymphoma, *PTCL-NOS* peripheral T cell lymphoma not otherwise specified, *ALCL ALK±* anaplastic large cell lymphoma, anaplastic lymphoma kinase positive/negative, *NKT* NK/T cell lymphoma, *CR* complete remission, *autoSCT* autologous stem cell transplant, *alloSCT* allogenic stem cell transplant

## Discussion

The poor prognosis of PTCL patients after treatment with conventional chemotherapy entails the need for alternative treatment strategies. Although new drugs have been evaluated recently (Dueck et al. 2010; Fanale et al. 2014; Gallamini et al. 2007; Horwitz et al. 2014; Piekarz et al. 2011), high-dose chemotherapy followed by autoSCT is still the mainstay of treatment intensification in PTCL. Nevertheless, despite numerous studies investigating its role in the treatment of PTCL (Corradini et al. 2006; d'Amore et al. 2006, 2012; Reimer et al. 2009; Rodriguez et al. 2007; Rodríguez et al. 2007), the status of frontline autoSCT after induction therapy has not been settled (Moskowitz et al. 2014). In this study, we present a single-center experience of 58 patients who underwent autoSCT either in the frontline or relapse setting, with the choice of treatment with regard to up-front autoSCT or observation at the discretion of the treating physician. Previous studies have shown that autoSCT, mostly in the context of progressive disease, is performed in only about two-thirds of patients with an intention to transplant at diagnosis (d'Amore et al. 2012; Ellin et al. 2014; Rohlfing et al. 2018). Our focus in this analysis on patients who actually underwent autoSCT allowed us to further characterize this group of patients and to evaluate outcomes after autoSCT in the both settings. Our cohort showed a markedly different distribution of PTCL subtypes when compared to other pro- and retrospective studies (Cederleuf et al. 2017; Corradini et al. 2006; d'Amore et al. 2012; Ellin et al. 2014; Fossard et al. 2017; Rohlfing et al. 2018). In particular, our cohort comprised a higher percentage of patients with the generally poor prognosis EATL and AITL subtypes. Only 8.6% of patients showed the more favorable ALK+ ALCL subtype, where autoSCT is not routinely performed (Moskowitz et al. 2014). Despite the adverse risk profile, overall and progression-free survival was comparable to similar previous analyses of unselected patient cohorts undergoing autoSCT (Nickelsen et al. 2009; Rohlfing et al. 2018; Smith et al. 2013). The more favorable prognosis of ALK+ ALCL has often been reason to exclude this subtype from analysis in PTCL studies (d'Amore et al. 2012; Fossard et al. 2017; Nickelsen et al. 2009; Reimer et al. 2009; Rohlfing et al. 2018). To give a realistic insight into a single center experience and considering the similar treatment approach, we decided to include these patients in our analysis. Other baseline characteristics in our study were similar to those of previous retrospective reports, with the exception of a slightly more favorable IPI distribution at diagnosis (Cederleuf et al. 2017; Ellin et al. 2014; Fossard et al. 2017; Rohlfing et al. 2018). The role of mobilization therapy prior to stem cell harvest is unsettled and frequently no defined mobilization regimen is applied, as the feasibility of PBSCT harvest following a regular induction cycle has been demonstrated (Corradini et al. 2006; d'Amore et al. 2012;

Moskowitz et al. 2014; Reimer et al. 2009). At our center, we aim to perform PBSCT harvest at the end of induction therapy, which entails the lowest risk for lymphoma contamination (Jacquy et al. 2000). A routinely implemented mobilization regimen allows for a reliable PBSCT harvest in these pretreated patients, as cytotoxic induction chemotherapy adversely affects the yield of CD34+ hematopoietic stem cells (Haas et al. 1994). Nevertheless, possible complications, such as infections due to prolonged neutropenia and transfusion requirements following mobilization therapy, have to be taken into consideration. No difference regarding outcome was observed between the two most common regimens used (DHAP and VIP-E) and whether the regimen included anthracyclines or not. In our cohort, no baseline characteristics other than ALK− ALCL subtype correlated significantly with outcome. This is partly in line with previous reports, where only few and varying factors (i.e. IPI, age, response to induction) have shown predictive value in multivariate analyses (Corradini et al. 2004; d'Amore et al. 2012; Rohlfing et al. 2018). This observation underscores the difficulty of establishing a universal prognostic tool for this heterogenous group of diseases and explains why adopted scores from B cell lymphomas have not shown the same prognostic value in PTCL (Gutiérrez-García et al. 2010; Piccaluga et al. 2010). Baseline characteristics were similar in the frontline and relapse autoSCT groups, arguing against a selection bias in deciding for and against up-front autoSCT. Considering the similar remission statuses prior to transplant in both patient groups, this allows for a cautious comparison of outcome after autoSCT, whilst keeping the natural limitations of a retrospective study in mind. Although widely practiced as standard of care and being recommended for transplant-eligible patients by several guidelines (d'Amore et al. 2015; Kharfan-Dabaja et al. 2017), no benefit for up-front autoSCT could be deduced from our data. In fact, a striking number of patients achieved long-time remission from autoSCT in the relapse setting, pointing towards a benefit for those patients eligible for autoSCT at relapse and thereby resembling the pattern seen in B cell lymphomas (Philip et al. 1995). However, it should be considered that a substantial fraction of relapsing patients may be ineligible for autoSCT due to disease progression or chemoresistant disease (Chihara et al. 2017; Ellin et al. 2014; Mak et al. 2013). Therefore, the markedly better OS and PFS seen in our relapse autoSCT group is likely exaggerated owing to a selection bias, as only fit patients with renewed chemosensitive disease were treated within this group. Nevertheless, delaying high-dose chemotherapy and autoSCT to a relapse setting might be a suitable approach for patients with a complete remission after conventional induction chemotherapy. While several studies have reported a survival benefit for autoSCT in first remission (Corradini et al. 2006; d'Amore et al. 2012; Reimer et al. 2009), our observations are comparable with more recent reports, where no such benefit was observed (Cederleuf et al. 2017; Fossard et al. 2017). Of note, nearly half of our patient cohort was ≥ 60 years old and no significant difference in OS and PFS was seen when compared to younger patients. This illustrates that autoSCT can also be considered in eligible older patients. As expected, patients relapsing after autoSCT had a particularly poor outcome. Remarkably, although no disease reoccurrence was observed, survival was only marginally improved through allogenic stem cell transplant in this setting. This observation is easily explained by the high transplant-related mortality observed in our cohort, which has not been reported to the same extend in previous studies (Hamadani et al. 2008; Kanakry et al. 2013; Le Gouill et al. 2008; Smith et al. 2013). Infectious complications were the main cause of TRM, mostly occurring in the immediate context of alloSCT. Resulting in an increased risk and reduced resilience to infections, this is likely a reflection of the impaired bone marrow and organ functions in this heavily pretreated patientcollective. Reduced intensity conditioning might therefore contribute to reducing TRM in these patients (Corradini et al. 2004). Furthermore, the frequently severe immune dysfunction observed in T cell lymphomas (Advani et al. 1980) has to be considered as a contributing factor. Our single-center experience adds another piece to the still incomplete picture on the role of autologous stem cell transplant in PTCL. Our study shows that long-term remission can be achieved through autoSCT in both the up-front and relapse setting. While no definitive conclusion can be drawn from our retrospective data, our study does not support autoSCT as an up-front treatment in patients with chemosensitive disease. The persistently inconsistent results obtained from retro- and prospective studies on the role of autoSCT in the frontline therapy of PTCL more than ever call for evaluation in a large randomized trial.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Research involving human participants and/or animals** This article does not contain any studies with human participants or animals performed by any of the authors.

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