Diagnosis of Toxoplasmosis after Allogeneic Stem Cell Transplantation: Results of DNA Detection and Serological Techniques

Hélène Fricker-Hidalgo,[1] Claude-Eric Bulabois,[2] Marie-Pierre Brenier-Pinchart,[1] Rebecca Hamidfar,[3] Frédéric Garban,[2] Jean-Paul Brion,[4] Jean-François Timsit,[3] Jean-Yves Cahn,[2] and Hervé Pelloux[1]

[1]Parasitologie-Mycologie, Pôle Biologie, [2]Hématologie, Pôle Cancérologie, and [3]Réanimation Médicale and [4]Maladie Infectieuse, Pôle Médecine Aigüe et Communautaire, Centre Hospitalier Universitaire, Grenoble, France

Background. The biological diagnosis of toxoplasmosis after allogeneic hematopoietic stem cell transplantation (HSCT) is based on the detection of *Toxoplasma gondii* DNA in blood specimens or other samples. Serological testing is used mainly to defin the immunity status of the patient before HSCT. The aim of our study was to examine the performance of polymerase chain reaction (PCR) and serological techniques in the diagnosis of toxoplasmosis after HSCT.

Methods. Seventy patients underwent allogeneic HSCT from September 2004 through September 2006. DNA was detected by PCR, and immunoglobulin G and immunoglobulin M were detected by enzyme-linked immunosorbent assay.

Results. The results of immunoglobulin G detection before allogeneic HSCT were positive in 40 (57.1%) of the patients and negative in 30 (42.9%). After HSCT, 57 patients (81.4%) had test results that were negative for immunoglobulin M and had negative results of DNA detection, without toxoplasmosis infection. Four patients (5.7%) had at least 4 samples with positive PCR results and/or test results positive for immunoglobulin M against *T. gondii;* toxoplasmosis was then confi med by clinical symptoms. Nine patients (12.9%) with positive PCR results and 1 or 2 samples with test results negative for immunoglobulin M were considered to have asymptomatic *T. gondii* infection. Reactivation of latent infection was the cause of toxoplasmosis in 3 of the 4 patients, and toxoplasmosis occurred as a primary infection in 1 patient. The detection of specifi anti–*T. gondii* immunoglobulin M was the only biological evidence of toxoplasmosis in 2 patients, and samples were positive for immunoglobulin M before PCR was performed in 1 patient.

Conclusions. Thus, after HSCT, all patients were at risk for toxoplasmosis; all patients who receive HSCTs should be followed up with biological testing that combines PCR and serological techniques.

Toxoplasmosis after allogeneic hematopoietic stem cell transplantation (HSCT) remains a cause of severe infection and is associated with a high mortality rate [1]. Various studies have estimated a toxoplasmosis risk of 0.3%–5.0% after allogeneic HSCT, depending on the prevalence of *Toxoplasma gondii* in the population [2–5], but the true incidence of toxoplasmosis among immunocompromised patients is difficul to assess, because in many instances, the diagnosis is overlooked [6]. Recent single-center and multicenter retrospective studies [7] have suggested that invasive disease may be more common than was previously known, with incidences among *T. gondii*–seropositive recipients of allogeneic transplants of up to 4% and an estimated mortality rate of 60%–90%. The major site of infection is the brain, with a focal mass presentation or, less commonly, diffuse encephalitis [3, 8]. Myocarditis, pneumonitis [9], hepatitis, chorioretinitis, and disseminated disease may also complicate the course of toxoplasmosis in immunocompromised hosts [1, 4]. The clinical presentation is nonspecific and the pleiomorphic manifestation of toxoplasmosis makes it difficul to obtain a definit antemortem diagnosis [10]. Studies underscore the need for rapid diagnostic tests in an effort to improve the outcome [2]. Serological testing is used

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Reprints or correspondence: Dr. Hélène Fricker-Hidalgo, Parasitologie-Mycologie, Pôle Biologie, Centre Hospitalier Universitaire, BP217, 38043 Grenoble, France (hfricker-hidalgo@chu-grenoble.fr).

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Table 1. Findings for 70 patients who received allogeneic hematopoietic stem cell transplants, according to PCR and IgM test results.

Test results	No. of patients	No. of positive samples	No. of patients with toxoplasmosis
PCR− and IgM−	57	0	0
PCR+ and IgM+	2	1 patient had 4 positive samples; 1 patient had 5 positive samples	2
PCR− and IgM+	1	5	1
PCR+ and IgM−	10	1 patient had 5 positive samples; 9 patients had 1 positive sample	1[a]

NOTE. IgM detection was performed using ELISA (Vidas; bioMérieux), immunosorbent agglutination assay (bioMérieux), and indirect immunofluorescence. *Toxoplasma gondii* DNA detection was performed using PCR. +, Positive; −, negative

[a] The patient with 5 positive samples.

mainly to identify at-risk patients prior to allogeneic HSCT [10]. PCR has been shown to be sensitive in immunocompromised patients with disseminated toxoplasmosis [11–14] and may represent a better modality for early identificatio of infection [10]. Routine PCR testing of peripheral blood specimens may be an appropriate tool to guide preemptive therapy for patients at very high risk of developing invasive disease [7, 15, 16].

The aim of this study was to retrospectively analyze the combined results of PCR and serological techniques in a survey of 70 allogeneic HSCT recipients and to determine the prevalence of invasive toxoplasmosis.

PATIENTS AND METHODS

Patients. Seventy consecutive adult patients received HSCTs from September 2004 through September 2006 in the Hematologic Department of Grenoble University Hospital (Grenoble, France). Serological testing was performed on baseline pretransplantation samples obtained from each patient. After transplantation, the patients were systematically monitored by PCR performed on blood samples obtained every 2 weeks during immunosuppressive treatment and were monitored less systematically by serological testing. If toxoplasmosis was suspected, PCR was performed more frequently (every 2 days) on blood samples and/or on another sample from the involved organ (usually CSF or bronchoalveolar lavage fluid) After engraftment, primary prophylaxis with trimethoprim-sulfamethoxazole was recommended for all patients when possible (~1 month after HSCT). Yet, if intolerance or persistent neutropenia occurred, alternative prophylaxis decisions were made. If a patient was found to have PCR results positive for *T. gondii* without clinical symptoms, no treatment was initiated. If a patient developed *Toxoplasma* disease, therapy including pyrimethamine-sulfadiazine or pyrimethamine-clindamycin was initiated on the basis of biological, clinical, and radiological evidence.

Methods. The parasite DNA was detected using a qualitative PCR system, described elsewhere [17], that was designed to use the B1 target gene and that uses an internal control to monitor inhibition, as well as an amplicon carry-over contamination control with a sensitivity level of 1 parasite. Anti–*T. gondii* IgM was detected by ELISA (Vidas; bioMérieux), indirect immunofluo escence, and immunosorbent agglutination assay (bioMérieux) [18]. Anti–*T. gondii* IgG was detected by ELISA (Vidas; bioMérieux) and indirect immunof uorescence [19].

Definitions *T. gondii* infection and disease were define according to the European Group for Blood and Marrow Transplantation–Infectious Diseases Working Party Guidelines [7]. In brief, *T. gondii* infection was define as being present in a patient who had positive results of PCR performed on blood samples and no evidence of organ involvement, with or without fever. Definit toxoplasmosis was define as histological evidence of active *Toxoplasma* disease found in a clinically and radiologically involved organ, whereas probable toxoplasmosis was define as positive results of PCR performed on a blood sample and/or another sample from the involved organ (usually CSF or bronchoalveolar lavage fluid with clinical signs and symptoms and radiological evidence of active disease.

RESULTS

Biological test results. Before HSCT, serological testing was performed to determine the immune status of the recipients. The results of specifi IgG detection testing were positive for 40 (57.1%) of 70 HSCT recipients. The results of specifi IgM detection testing were negative for 69 (98.6%) of 70 HSCT recipients; the 1 HSCT recipient with positive results had residual IgM detected. After HSCT, 4 recipients (5.7%) who had *Toxoplasma* disease had at least 4 samples with positive biological test results (i.e., presence of *T. gondii* DNA or IgM or both) (table 1). The 57 patients (81.4%) with negative IgM test results and negative DNA detection results had no *T. gondii* infection. The 9 other patients (12.8%), who had 1 or 2 samples with positive PCR results and negative IgM results, were con-

sidered to have *T. gondii* infection without disease; these patients experienced a favorable outcome without any specif c antitoxoplasmic treatment. The predictive value of having 1 sample with a positive PCR result was 25%. Thus, the incidence of *Toxoplasma* disease was 5.7%, and the incidence of *T. gondii* infection was 12.8%.

Characteristics and outcome of* Toxoplasma *disease. Characteristics and outcomes of the 4 recipients with toxoplasmosis are shown in table 2. These 4 recipients received suppressive treatment, but 3 recipients (patients 1, 2, and 3) received transplants from unrelated donors and developed graft-versus-host disease of grade I or II. None of the patients had received anti-*T. gondii* prophylaxis. Two recipients (patients 1 and 2) developed cerebral toxoplasmosis, and the other 2 recipients (patients 3 and 4) developed disseminated toxoplasmosis with respiratory distress. The disease onset was earlier for the 2 recipients with pulmonary symptoms (patient 3, onset at day 27; patient 4, onset at day 33) than for the 2 recipients with neurological symptoms (patient 1, onset at day 114; patient 2, onset at day 153). Before the allograft was performed, 3 recipients (patients 2, 3, and 4) had serological test results that were positive for *T. gondii* IgG. In patients 2, 3, and 4, toxoplasmosis seemed to occur through reactivation of latent cysts into invasive tachyzoites. In patient 1, the recipient and the donor were seronegative, the results of PCR performed on 10 blood samples and 1 CSF sample were negative, and toxoplasmosis occurred as a primary infection with a typical seroconversion (figu e 1*A*). The symptoms included abnormal movements of all 4 limbs and of the eyes. Treatment with pyrimethamine-clindamycine was effective. Patient 2 had fever and somnolence. Two peripheral blood samples yielded positive PCR results on days 165 and 168 after transplantation (figu e 1*B*) and confi med the presence of toxoplasmosis. The results of a PCR performed on 1 CSF sample were negative. Subsequently, 2 relapses of toxoplasmosis were observed after stopping antiparasitic treatment. The results of biological testing performed after the firs relapse were negative, and the diagnosis was confi med by a cerebral CT. A second relapse occurred on day 800, and biological test results revealed an increased IgM level, but PCR results were negative. Patient 3, who had pulmonary toxoplasmosis, received a toxoplasmosis diagnosis on the basis of positive results of PCR performed on bronchoalveolar lavage fluid but the patient died before treatment could be administered (figu e 1*C*). A retrospective analysis of the serum samples obtained 27, 34, 43, and 49 days before this patient's death revealed the presence of IgM. Patient 4 received a diagnosis on the basis of positive results of PCR performed on bronchoalveolar lavage flui on day 36 after transplantation (figu e 1*D*). Giemsa fast staining and microscopic observation of the bronchoalveolar lavage flui sample obtained on day 46 revealed tachyzoites of *T. gondii.* In this case, tests to detect IgM had negative results. Treatment with pyrimethamine-clindamycin was started, but the patient died on day 59.

Characteristics and outcome of* T. gondii *infection. Table 3 shows the demographic and clinical characteristics and outcomes for the 9 patients with 1 or 2 blood samples with positive PCR results. Before the allograft was received, 6 of 9 recipients had serological tests with results that were positive for *T. gondii* (i.e., positive for IgG). In 6 patients, the serostatus of the donor was positive, and 3 patients (patients 10, 11, and 12) received transplants from unrelated donors. Seven patients (patients 5, 6, 7, 9, 10, 12, and 13) received suppressive treatment, and 4 patients (patients 5, 9, 10, and 12) developed graft-versus-host disease of grade I or II. Only 1 of 9 patients received anti-*T. gondii* prophylaxis. No signs of toxoplasmosis were observed. The 9 patients did not receive treatment with anti–*T. gondii* drugs, and the outcomes were favorable for all patients.

DISCUSSION

Few studies [1, 3, 20] have analyzed the incidence of *T. gondii* infection and disease in patients after allogeneic HSCT. Martino et al. [7] described the results of a prospective study of the incidence of reactivation of toxoplasmosis that was performed at 5 European transplantation centers and involved 106 *T. gondii*–seropositive adult recipients of HSCT. They found an incidence of 16% for *T. gondii* infection and 6% for *Toxoplasma* disease. In our study, the incidence of *T. gondii* infection was 12.8%, and the incidence of *Toxoplasma* disease was 5.7%. However, the patients in our study had positive or negative serological test results obtained before HSCT. The seropositive patients were at risk for reactivation of latent cysts, whereas the seronegative patients were at risk for primary *T. gondii* infection. Thus, toxoplasmosis is more common after HSCT than has been previously suggested [2–5]. The incidence of toxoplasmosis in our study approximated that in the study by Martino et al. [7].

Toxoplasmosis after HSCT is a severe infection that is associated with a high mortality rate [1, 10, 21]. Analysis of our data also indicates that infections that occur late after transplantation (e.g., patients 1 and 2; table 2) may have a better prognosis than infections that occur soon after transplantation (e.g., patients 3 and 4). The low rate of late reactivation is probably attributable to the fact that immune recovery improves with time after HSCT [1]. The patients who received HSCTs from unrelated donors (3 of the 4 recipients in our study) possibly had a higher risk of toxoplasmosis than did patients who received HSCTs from related donors. PCR techniques to detect the presence of *T. gondii* DNA in peripheral blood and other samples may help to establish the toxoplasmosis diagnosis [14, 22]. The PCR used in this work was qualitative. However, this is not a major drawback, because no clear threshold level for therapy has been described to date. Our

Table 2. Clinical characteristics of patients with toxoplasmosis.

Variable	Patient 1	Patient 2	Patient 3	Patient 4
Age, years	50	49	54	45
Sex	F	M	F	F
Underlying disease	Myeloma	Myeloma	Vasquez disease	Medullary aplasia
Donor type (stem cell source)	UD (CB)	UD (PBSCs)	UD (PBSCs)	HLA-identical sibling (PBSCs)
IgG test results, patient/donor	−/−	+/−	+/+	+/−
GVHD (grade)	Acute (I)	Acute (II)	Acute (I)	Not present
Immunosuppresive treatment	Cyclosporin	Tacrolimus, prednisone	Cyclosporin, prednisone	Cyclosporin, prednisone, mycophenolate
PCR results, proportion of positive samples (no. of days from HSCT to first positive result)	0/11	2/29 (160)	1/3 (56)	5/7 (35)
IgM test results, proportion of positive samples (no. of days from HSCT to first positive result)	5/10 (114)	2/14 (803)	4/4 (27)	0/4
Signs of toxoplasmosis (no. of days from HSCT to symptom onset)	Abnormal movements of limbs and eyes (114)	Fever, somnolence (153, 340, 803)	Fever, hyperpnea (27)	Respiratory distress (33)
Therapy for toxoplasmosis	Pyrimethamine-clindamycin	Pyrimethamine-sulphadiazine and pyrimethamine-clindamycin	None	Pyrimethamine-clindamycin
Outcome and comments	Alive and well 1 year after cerebral toxoplasmosis	Alive; experienced 2 relapses of cerebral toxoplasmosis	Died on day 56 of disseminated toxoplasmosis and reactivation of CMV infection	Died on day 59 of disseminated toxoplasmosis and CMV infection

NOTE. None of the patients had received anti–*T. gondii* prophylaxis before HSCT. CB, cord blood; CMV, cytomegalovirus; GVHD, graft-versus-host disease; PBSCs, peripheral blood stem cells; UD, unrelated donor; +, positive; −, negative.

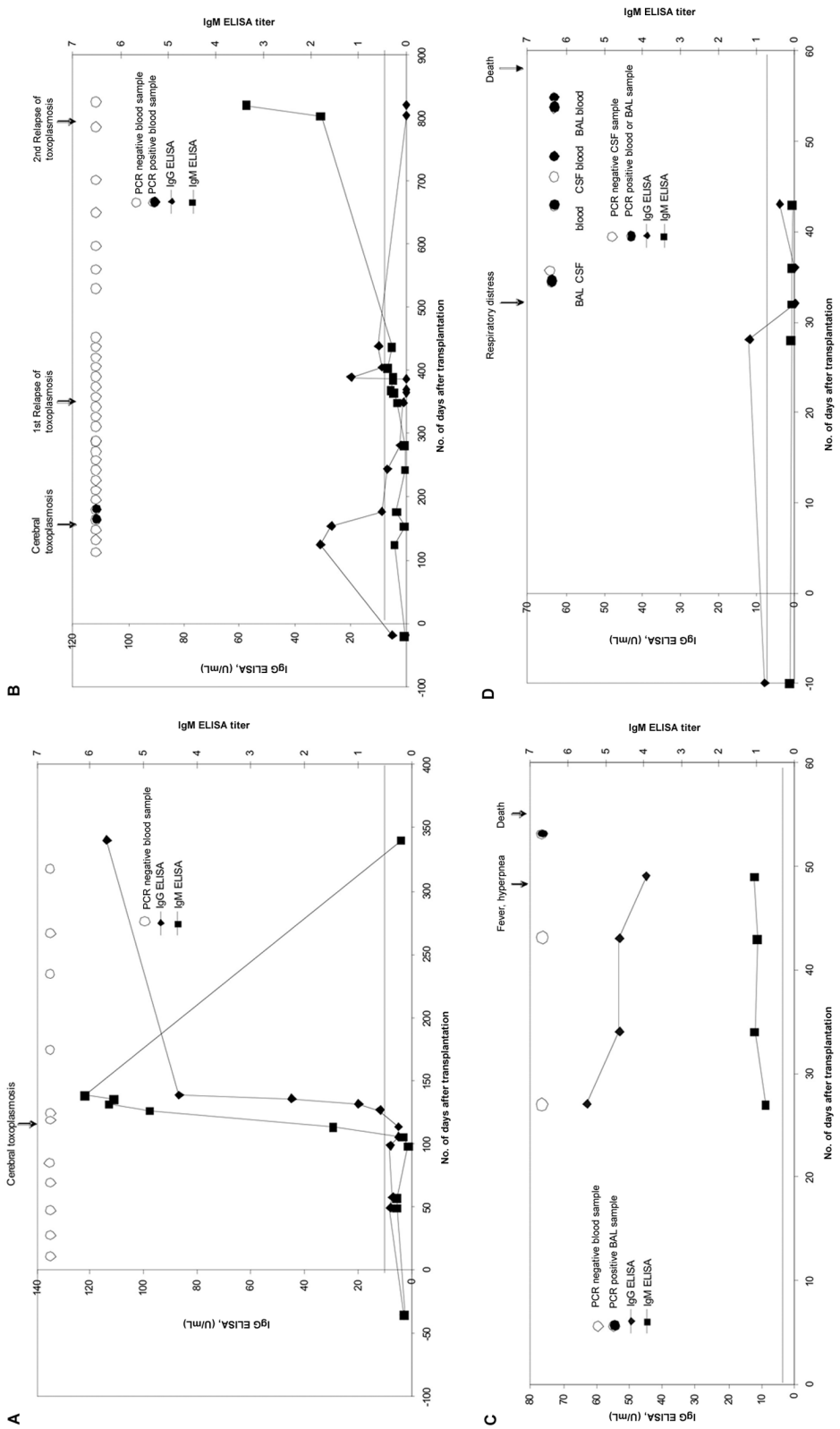

Figure 1. Results of IgM and IgG detected by ELISA (Vidas; bioMérieux) and *Toxoplasma gondii* DNA detected by PCR testing of blood samples, CSF samples, and bronchoalveolar lavage fluid (BAL) samples. For detection of IgM by ELISA, a titer of <0.55 was defined as negative, >0.65 was defined as positive, 0.55–0.65 was defined as equivocal. For detection of IgG by ELISA IgG, <4 U/mL was defined as negative, >7 U/mL was defined as positive, and 4–7 U/mL was defined as equivocal. *A*, Patient 1, who had a diagnosis of cerebral toxoplasmosis; *B*, patient 2, who had a diagnosis of cerebral toxoplasmosis; *C*, patient 3, who had a diagnosis of pulmonary toxoplasmosis; *D*, patient 4, who had a diagnosis of pulmonary toxoplasmosis.

Table 3. Clinical and demographic characteristics of patients with at least 1 PCR result positive for *Toxoplasma gondii* infection.

Variable	Patient 5	Patient 6	Patient 7	Patient 8	Patient 9	Patient 10	Patient 11	Patient 12	Patient 13
Age, years	64	41	22	46	35	17	57	59	43
Sex	M	M	M	M	M	M	F	M	F
Underlying disease	Lymphoma	Lymphoma	ALL	CML	ALL	AML	Medullary aplasia	Myelofibrosis	Paroxysmal hemoglobinuria
Donor type (stem cell source)	HLA-identical sibling (PBSCs)	HLA-identical sibling (PBSCs)	HLA-identical sibling (PBSCs)	HLA-identical sibling (PBSCs)	HLA-identical sibling (PBSCs)	UD (PBSCs)	UD (PBSCs)	UD (PBSCs)	HLA-identical sibling (PBSCs)
IgG test results, patient/donor	+/+	−/−	−/+	+/−	+/−	−/−	+/+	+/−	+/−
GVHD (grade)	Acute (I)	Not present	Not present	Not present	Acute (II)	Acute (II)	Not present	Acute (II)	Not present
Immunosuppresive treatment	Cyclosporin	Mycophenolate	Cyclosporin	None	Cyclosporin, prednisone	Cyclosporin, prednisone	None	Cyclosporin, mycophenolate	Cyclosporin
PCR results, proportion of positive samples	1/6	2/8	1/10	1/4	2/23	1/15	1/9	1/12	1/9
IgM test results, proportion of positive samples	0/6	0/10	0/7	0/5	0/9	0/7	0/8	0/8	0/10
Time to first positive biological test result after HSCT, days	38	241	92	16	83	2	177	32	166
Receipt of prior anti–*T. gondii* prophylaxis	None	None	None	None	None	None	None	None	Trimethoprim-sulfamethoxazole
Outcome and comments	Alive	Alive	Alive	Alive	Died on day 206 of polyvisceral failure	Alive	Alive	Alive	Alive

NOTE. None of these patients had signs of toxoplasmosis, and none received therapy for toxoplasmosis. ALL, acute lymphoblastic leukaemia; AML, acute myelogenous leukaemia; CML, chronic myelogenous leukaemia; GVHD, graft-versus-host disease; PBSCs, peripheral blood stem cells; UD, unrelated donor; +, positive; −, negative.

study shows that the detection of IgM may be important for obtaining a diagnosis of toxoplasmosis in some patients. For 2 patients, the detection of specifi anti–*T. gondii* IgM was the only biological evidence of toxoplasmosis (patient 1) or relapse (patient 2). For 1 patient (patient 3), IgM was detected before positive PCR results were obtained. For the biological follow-up of patients undergoing allogeneic HSCT, no consensus exists on the optimal protocol to be used in clinical laboratories. We recommend monitoring by PCR of blood samples and serological testing once every 2 weeks during immunosuppressive therapy after transplantation.

Reactivation of latent tissue cysts in previously infected individuals is the usual mechanism involved in toxoplasmosis that occurs after HSCT [1]. Therefore, it is important to determine the patient's serostatus before transplantation and to monitor the patient with negative specifi serological tests to detect potential new infection. Three patients with toxoplasmosis infection were seronegative before transplantation but had test results that were positive for IgG after HSCT. A negative test result obtained before allograft does not always mean the absence of *T. gondii* immunity, because deep immunosuppression may reduce the level of anti–*T. gondii* antibodies. Therefore, all of the patients with test results negative for IgG before allograft, as well as those with test results positive for IgG, should be followed up with PCR and serological testing. The need for *T. gondii* prophylaxis before HSCT in transplant recipients should be better defined and *T. gondii* prophylaxis should preferably be combined with *Pneumocystis jiroveci* prophylaxis [6]. For prophylaxis, we propose the use of cotrimoxazole or pyrimethamine combined with pentamidin.

In conclusion, toxoplasmosis is a serious health problem among HSCT recipients that can lead to death. Reactivation of latent infection is the most common cause of toxoplasmosis in such patients. However, toxoplasmosis can also occur as a primary infection. After allogeneic HSCT, all patients are at risk of toxoplasmosis and should be followed up with biological testing. We recommend the use of PCR performed on blood samples and serological testing to detect anti–*T. gondii* IgM and IgG.

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Potential confl cts of interest. All authors: no conf icts.

References

1. Martino R, Maertens J, Bretagne S, et al. Toxoplasmosis after hematopoietic stem cell transplantation. Clin Infect Dis **2000**; 31:1188–94.
2. Small TN, Leung L, Stiles J, et al. Disseminated toxoplasmosis following T cell–depleted related and unrelated bone marrow transplantation. Bone Marrow Transplant **2000**; 25:969–73.
3. Lim Z, Baker B, Zuckermann M, et al. Toxoplasmosis following alemtuzumab-based allogeneic haematopoietic stem cell transplantation. J Infect **2007**; 54:e83–6.
4. Singh N, Husain S. Infections of the central nervous system in transplant recipients. Transpl Infect Dis **2000**; 2:101–11.
5. Au WY, Cheng VCC, Lie AKW. *Toxoplasma gondii* serology and stem cell transplantation in Chinese. Transplant Proc **2005**; 37:4497–9.
6. Aoun M, Georgala A, Mboumi K, et al. Changing the outcome of toxoplasmosis in bone marrow transplant recipients. Int J Antimicrob Agents **2006**; 27:570–5.
7. Martino R, Bretagne S, Einsele H, et al. Early detection of *Toxoplasma* infection by molecular monitoring of *Toxoplasma gondii* in peripheral blood samples after allogeneic stem cell transplantation. Clin Infect Dis **2005**; 40:67–78.
8. Walker M, Zunt J. Parasitic central nervous system infections in immunocompromised hosts. Clin Infect Dis **2005**; 40:1005–15.
9. Eza DE, Lucas SB. Fulminant toxoplasmosis causing fatal pneumonitis and myocarditis. HIV Med **2006**; 7:415–20.
10. Goebel WS, Conway JH, Faught P, Vakili ST, Haut PR. Disseminated toxoplasmosis resulting in graft failure in a cord blood stem cell transplant recipient. Pediatr Blood Cancer **2007**; 48:222–6.
11. Menotti J, Vilela G, Romand S, et al. Comparison of PCR–enzyme-linked immunosorbent assay and real-time PCR assay for diagnosis of an unusual case of cerebral toxoplasmosis in a stem cell transplant recipient. J Clin Microbiol **2003**; 41:5313–6.
12. Held TK, Krüger D, Switala AR, et al. Diagnosis of toxoplasmosis in bone marrow transplant recipients: comparison of PCR-based results and immunohistochemistry. Bone Marrow Transplant **2000**; 25: 1257–62.
13. Martino R, Bretagne S, Rovira M, et al. Toxoplasmosis after hematopoietic stem transplantation: report of a 5-year survey from the Infectious Diseases Working Party of the European Group for Blood and Marrow Transplantation. Bone Marrow Transplant **2000**; 25:1111–4.
14. Matsuo Y, Takeishi S, Miyamoto T, et al. Toxoplasmosis encephalitis following severe graft-*vs*.-host disease after allogeneic hematopoietic stem cell transplantation: 17 yr experience in Fukuoka BMT group. Eur J Haematol **2007**; 79:317–21.
15. Kompalic-Cristo A, Frotta C, Suàrez-Mutis M, Fernandes O, Britto C. Evaluation of a real-time PCR assay based on the repetitive B1 gene for the detection of *Toxoplasma gondii* in human peripheral blood. Parasitol Res **2007**; 101:619–25.
16. Hierl T, Reischl U, Lang P, et al. Preliminary evaluation of one conventional nested and two real-time PCR assays for the detection of *Toxoplasma gondii* on immunocompromised patients. J Med Microbiol **2004**; 53:629–32.
17. Pelloux H, Guy E, Angelici MC, et al. A second European collaborative study on polymerase chain reaction for *Toxoplasma gondii,* involving 15 teams. FEMS Microbiol Lett **1998**; 165:231–7.
18. Montoya JG, Liesenfeld O. Toxoplasmosis. Lancet **2004**; 363:1965–76.
19. Roux-Buisson N, Fricker-Hidalgo H, Foussadier A, et al. Comparative analysis of the VIDAS Toxo IgG IV assay in the detection of antibodies to *Toxoplasma gondii*. Diagn Microbiol Infect Dis **2005**; 53:79–81.
20. Chandrasekar PH. Real-time polymerase chain reaction for early diagnosis of toxoplasmosis in stem cell transplant recipients: ready for prime time? Clin Infect Dis **2005**; 40:79–81.
21. Weinrach DM, Oviedo A. Toxoplasmosis in a bone marrow transplant patient. Arch Pathol Lab Med **2001**; 125:707.
22. Brenier-Pinchart MP, Garban F, Fricker-Hidalgo H, Richard MJ, Makowski C, Pelloux H. Avoidance of *Toxoplasma gondii* transmission from a recently infected donor to the recipient of hematopoietic stem cell transplantation. Bone Marrow Transplant **2005**; 35:735–6.