original article

Mycobacterium tuberculosis in solid organ transplantation: incidence before and after expanded isoniazid prophylaxis

Suad Mohamed Al-Mukhaini,[a] Hassan Al-Eid,[b] Fatima Alduraibi,[a] Hanan Ibrahim Hakami,[a] Haifa Al Talhi,[a] Mohamed Shoukri,[c] Ahmed M. Ahmed,[d] Yusuf Ahmed,[e] Abdulrahman A. Alrajhi[a]

From the [a]Department of Medicine, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia, [b]Department of Kidney and Pancreas Transplantation, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia, [c]Department of Cell Biology, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia, [d]Department of Infection Control and Environmental Health, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia, [e]Department of Quality, King Khalid University Hospital, Riyadh, Saudi Arabia

Correspondence: Dr. Suad Mohamed Al-Mukhaini · Sur Hospital Medicine, South Sharqia, PO Box 955 Sur, 411, Oman · T: 968 25561100, F: 968 25561561 · almukhainism@gmail.com · ORCID: http://orcid.org/0000-0003-0646-4378

Ann Saudi Med 2017; 37(2): 138-143

DOI: 10.5144/0256-4947.2017.138

BACKGROUND: The risk of tuberculosis is increased in solid organ transplantation. Rates remain high in developed and developing countries. We developed protocols to better identify transplant recipients at risk of tuberculosis and initiate interventions to prevent tuberculosis.
OBJECTIVES: Report tuberculosis incidence in solid-organ transplant recipients and the results of expanded isoniazid prophylaxis in deceased-donor renal transplantation.
DESIGN: Retrospective cohort study, comparing two time periods.
SETTING: Large transplantation center in a WHO-medium endemicity country for tuberculosis.
METHODS: In a cohort of all solid-organ transplant recipients performed between 2003 and 2012, tuberculosis-free transplantation follow-up is used for incidence calculation. Rates of tuberculosis in renal transplant recipients are compared before and after implementation of expanded isoniazid prophylaxis.
MAIN OUTCOME MEASURE(S): Active tuberculosis post-transplantation.
RESULTS: Of 1966 solid-organ transplant recipients (kidney: 1391, liver: 426, heart: 114, lung: 35), 20 recipients (1.02%) developed tuberculosis. Twelve cases (60%) developed tuberculosis within one year of transplantation. The incidence was 248 cases per 100 000 transplant-years. The proportion of transplant recipients (incidence of tuberculosis per 100 000 transplant-years) for specific organs were kidney 0.58% (127), liver 1.88% (594), heart: 1.75% (570), and lung 5.71% (4750). In the survival analysis, lung transplant recipients had significantly higher rates of tuberculosis compared to recipients of kidneys from living donors (P=.0001) with a rate ratio of 45.3 (95% CI: 7-313). Mortality was 5% among tuberculosis patients. After implementing expanded isoniazid prophylaxis among deceased-donor kidney recipients, no tuberculosis occurred in 177 recipients, compared to 3 out of 155 (2%) recipients before implementation.
CONCLUSIONS: Rates of tuberculosis among our solid transplant recipients are decreasing. Universal isoniazid prophylaxis in transplant recipients could reduce transplant-associated tuberculosis in endemic areas.
LIMITATIONS: Donor data on tuberculosis exposure and prevention and tuberculosis prevention efforts before referral to our center are not available for all patients.

Tuberculosis in solid organ transplantation (SOT) is one of the most challenging complications in both developed and developing countries. Recipients of SOT are at increased risk of tuberculosis by 20-74 times that of the general population.[1] In developing countries, the limited data indicate rates up to 100 times that of the general population.[2] The proportion of renal transplant recipients who develop tuberculosis in developing countries ranges between 3.5% and 14.5%.[3-6] In developed countries where population rates of active tuberculosis are low (less than 20 per 100 000), only 0.26% to 6.5% of transplant recipients develop tuberculosis.[7-9] Tuberculosis continued to be a major problem as recently as 2007 even in a large transplant

center in New York, where they reported an incidence 10-30 times higher than general population during the same period in the same location.[9] Incidence rates of tuberculosis in SOT recipients vary widely. Factors influencing these rates include geography, tuberculosis epidemiology, and time periods. Rates also vary based on transplanted organs and immunosuppressive regimens. Efforts of transplant programs to identify latent tuberculosis infection (LTBI) and prevent tuberculosis reactivation or acquisition in SOT recipients also reduce tuberculosis among transplant recipients. Tuberculosis in SOT recipients results in high morbidity and mortality even in experienced transplant centers in developed countries. Mortality in the United States in patients with tuberculosis after SOT was reported as 38%.[7] Tuberculosis in non-renal SOT recipients is reported mainly from North America and Europe.[7] Reports of tuberculosis in liver, heart, and lung transplant recipients are scarce from developing countries where tuberculosis rates in the general population remain high.

Because of the significant impact and cost of tuberculosis in SOT recipients, several authorities have developed and published guidelines to prevent and treat tuberculosis in the SOT population.[10-12] The main preventive measure is to diagnose LTBI in patients with end organ failure requiring transplantation and then initiate chemoprophylaxis using isoniazid. However, the tools to diagnose LTBI and therapeutic options for prophylaxis remain limited.[12]

In the 1980s, our center reported an active tuberculosis rate of 3.5% in renal transplant recipients,[4] which would translate to an annual incidence rate 50 times higher than the rate in the general population at that time. In 2008, our renal transplant program adopted a new approach of expanded isoniazid prophylaxis. All recipients of kidneys from deceased donors or living donors with evidence of LTBI in the donor were given isoniazid prophylaxis for nine months. In this report, we present the incidence of tuberculosis among SOT recipients from a single large transplant center in a WHO-medium endemicity country for tuberculosis (20-40 cases per 100000).[13] We also report the impact of expanded isoniazid prophylaxis in renal transplant recipients on rates of active tuberculosis.

PATIENTS AND METHODS

The King Faisal Specialist Hospital and Research Centre is a tertiary care center in Riyadh with 900 beds. It encompasses a large oncology and solid-organ transplant center with more than 700 transplantations of solid organs and hematopoietic cells a year. This study included a cohort of all SOTs done in the institution between January 2003 and December 2012. The solid organs we included are kidney, liver, lung, and heart. The center also cares for patients who received their organ transplantation elsewhere and were referred for further care. These patients are not included in the study as we do not have their pre-transplantation work up available in the database. Patients who received more than one transplanted organ and had a repeat transplantation after failure were counted once only. The date of their first transplantation procedure was used to measure follow-up duration and tuberculosis-free survival. An active tuberculosis infection was defined by culturing *Mycobacterium tuberculosis* from patient specimens (microbiological confirmation), by histopathological evidence of granuloma plus response to antituberculosis therapy in the absence of other explanations of the disease (histopathological confirmation), or a positive *M tuberculosis* complex DNA from patient specimens plus response to antituberculosis therapy in the absence of other explanation of the disease (molecular confirmation). Latent tuberculosis infection is defined by a positive tuberculin skin test (TST) in the recipient ≥10 mm, and in the donor ≥15 mm induration 48-72 hours after intradermal injection of 5 IU of purified protein derivative, or a positive interferon-gamma release assay (QuantiFERON-TB Gold In-Tube, Cellestis, Melbourne, Australia) using the manufacturer's criteria. Testing for LTBI was performed as part of pre-transplantation work-up.

The demographic data collected on patients with active *M tuberculosis* in SOT recipients included transplantation details, date of onset of tuberculosis infection, confirmation of active tuberculosis, comorbid conditions, and medications. Information was abstracted from the transplantation database, infection control records, tuberculosis laboratory data, and also by reviewing the medical records of SOT recipients. Incidence rates were calculated per 100000 transplant-years, with the denominator being the sum of transplant-years contributed by each transplanted organ after the date of transplantation without or prior to developing tuberculosis.

For transplanted kidneys, we compared active tuberculosis-free survival before and after the expanded isoniazid prophylaxis program which started in January 2008. In that program, 300 mg of isoniazid orally for nine months was given to all recipients of kidneys from deceased donors and from living donors with evidence of LTBI. It was started two weeks after transplantation. The primary end point was confirmation of tuberculosis. The end of follow-up duration was the onset of active tuberculosis infection or patient's death. Statistical anal-

yses were performed using IBM SPSS Statistics 21.The *t* test was used for calculating continuous variables and chi square or Fisher exact test for proportions. Kaplan-Meier survival analysis was used to compare time free of active tuberculosis infection between various transplanted organs. Additionally, tuberculosis-free time was compared among renal transplant recipients before and after the expanded isoniazid prophylaxis. The study was approved by the Institution Review Board (IRB) and a consent waiver was obtained (RAC # 2121 074).

RESULTS

During the study period, 1966 patients received solid organ transplantation of a kidney (1391), liver (426), heart (114), or lung (35) at King Faisal Specialist Hospital and Research Centre, Riyadh. Twenty recipients (1.02%) developed tuberculosis. **Table 1** summarizes the incidence rates of tuberculosis for the transplanted organs. Seven patients (35%) had pulmonary tuberculosis, 7 (35%) had both pulmonary and extrapulmonary tuberculosis, and 6 (30%) had extrapulmonary tuberculosis. All patients with active tuberculosis had laboratory confirmation, 18 with microbiological confirmation (*M tuberculosis* was isolated), and the remaining 2 cases had histopathological and molecular confirmation. Active tuberculosis occurred within the first year after transplantation in 12 patients (60%), and the median time to tuberculosis development was 9.2 months (range 1-70 months).

Table 2 summarizes the demographics and types of tuberculosis in the 20 recipients who developed tuberculosis. Compared to patients who received a kidney from a living donor, recipients of livers from a deceased donor and lung transplant recipients had significantly higher rates for developing active tuberculosis (2.2% and 5.7% respectively; *P* value of .02 and .006). Of note, there were 8 patients who received commercial transplantation outside Saudi Arabia and subsequently developed tuberculosis. These were not included in this study as we do not have the total number of commercial organ transplantation to calculate the rates and incidence of tuberculosis for this group.

One cadaveric-liver recipient died (5% mortality rate) for a non-tuberculosis related cause (cardiac cause). Cure without any documented relapse was achieved in 19 patients (95%). There was one relapse due to poor compliance to treatment. Rejection was documented in 9 patients (45%), and two transplanted kidneys were lost.

Kaplan-Meier analysis of survival probabilities of tuberculosis-free follow-up for the different transplanted organs showed that only lung transplantation had a significantly lower survival rates when compared to recipients of kidneys from living-related donors (*P*<.0001 using the log rank chi square test, **Figure 1**). Similarly, we compared the incidence rates of tuberculosis among the recipients of different transplanted solid organs as rate ratios using recipients of kidneys from living-related donors as a reference. Only lung transplantation was associated with 45 times higher risk of tuberculosis (95% CI: 6.6-313). The rate ratios are summarized in **Table 3**.

Among recipients of a kidney from a deceased donor (total 332), 155 recipients received the organ before January 2008, and 3 patients (2%) developed tuberculosis for an incidence of 290 cases per 100000 transplant-years. From January 2008 until December 2012, 177

Table 1. Tuberculosis rates per 100000 transplant-years between January 2003 and December 2012.

Transplanted Organ	Number in cohort	Total follow-up (transplant-years)	Number of tuberculosis cases	Proportion with tuberculosis	Incidence per 100000 transplant-years (95% CI)	*P* value*
Kidney-living donor	1059	4746	5	0.47%	105 (20-710)	- - - - -
Kidney-deceased donor	332	1571	3	0.90%	190 (50-790)	.62
Liver-living donor	202	509	3	1.49%	590 (260-1320)	.24
Liver-deceased donor	224	838	5	2.23%	597 (270-1330)	.02
Heart	114	351	2	1.75%	570 (250-1300)	.29
Lung	35	42	2	5.71%	4750 (360-6300)	.006
Total	**1966**	**8057**	**20**	**1.02%**	**248**	

**P* value testing the significance in rate of active tuberculosis compared to recipients of a kidney from a living-related donor as a reference group.

Table 2. Demographics of 20 tuberculosis cases in solid organ transplantation.

Case no.	Age, Sex	Type of SOT	Type of tuberculosis	Months between transplantation and tuberculosis diagnosis
1	54, F	Renal, cadaveric	Disseminated	7.3
2	47, M	Renal, living	Disseminated	4.8
3	48, M	Renal, cadaveric	Miliary	2.1
4	48, M	Renal, living	Adenitis	2.3
5	31, M	Renal, cadaveric	Pulmonary	70.0
6	65, M	Renal, living	Miliary, meningitis	7.7
7	52, M	Liver, cadaveric	Pulmonary, adenitis	12
8	58, M	Liver, cadaveric	Pulmonary	66.2
9	59, M	Liver, living	Miliary	64.3
10	26, F	Liver, cadaveric	Pulmonary	43.5
11	59, M	Liver, living	Abdominal	1.7
12	60, M	Liver, cadaveric	Adenitis	8.5
13	15, F	Lung	Pulmonary	1.0
14	47, M	Lung	Pulmonary	9.8
15	28, F	Heart	Disseminated	2.3
16	46, M	Heart	Bone	58.1
17	64, F	Renal, living	Pulmonary	3.1
18	54, M	Liver, cadaveric	Liver	37.0
19	64, F	Liver, living	Pulmonary	15.5
20	66, M	Renal, living	Adenitis	38.2

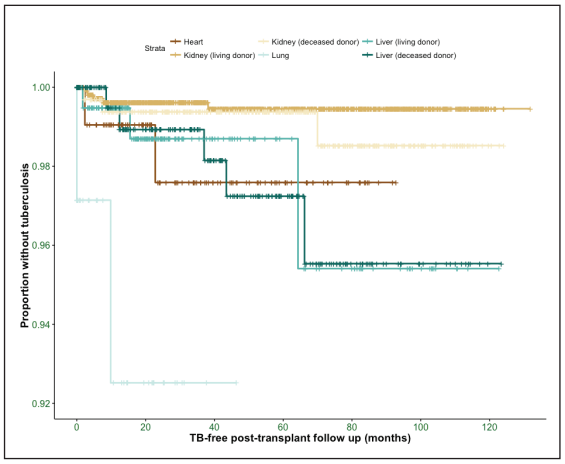

Figure 1. Tuberculosis-free Kaplan-Meier survival analysis for various transplant organ groups.

patients received isoniazid for nine months as part of the expanded prophylaxis program. At the conclusion of the study period and after a total follow-up duration of 530 transplant-years (average follow-up duration of 3 years), no recipient developed tuberculosis. Adverse effects of isoniazid in this group were limited to mild liver enzyme elevation (less than double the upper limit) without clinical symptoms.

DISCUSSION

In the United States, in 2010 alone, there were 45 cases of tuberculosis in SOT recipients reported to the CDC.[14] The majority of tuberculosis cases in SOT are related to activation of LTBI. Of all cases of active tuberculosis occurring after transplantation, 20-25% are in patients who had positive TST reactions before transplantation or LTBI diagnosed by other tools.[15,16] Patients with end organ failure may have anergy and LTBI may be under-diagnosed using TST. Another source of tuberculosis in SOT is from donor organs.[17,18] The efforts of transplant

Table 3. Incidence rate ratio for active tuberculosis in various transplant organ groups compared to recipients of kidneys from a living-donor for transplants between January 2003 and December 2012.

Transplanted organ	Number in cohort	Total follow-up (transplant-years)	Number of tuberculosis cases	Rate ratio	95% Confidence Interval on rate ratio	*P* value
Kidney-living donor	1059	4746	5	1	- - - - -	- - - - -
Kidney- deceased donor	332	1571	3	1.81	0.17-19.6	NS
Liver-living donor	202	509	3	5.62	0.7-44.8	NS
Liver-deceased donor	224	838	5	5.69	0.7-45.3	NS
Heart	114	351	2	5.43	0.7-43.5	NS
Lung	35	42	2	45.3	6.6-313	<0.01

Table 4. Incidence rates of tuberculosis in solid organ transplants and mortality from selected previous reports.

Author, year	Country	Transplanted organs	Number of transplants	Incidence per 100 000 transplant-years	Fatality
Qunibi, 1990[4]	Saudi Arabia	Kidney	403	3226	14%
Lattes, 1999[2]	Argentina	Kidney	384	3100	14%
Ergun, 2006[25]	Turkey	Kidney	283	3500	20%
Torre-Cisneros, 2009[8]	Spain	Kidney, pancreas, liver, lung, heart	4388	512	19%
Lopez de Castilla, 2010[9]	New York, USA	Kidney, liver, lung, heart	4925	264	15%
Al-Mukhaini, 2017 (Present study)	Saudi Arabia	Kidney, liver, lung, heart	1966	248	5%

programs to prevent reactivation of LTBI have focused mainly on the recipients. Recently, screening donors for LTBI has been implemented in many programs.[18,19] In our organization, we started screening living-related kidney donors for LTBI in 2001. Performing TST on deceased donors is not practical.[19] As the majority of the deceased donors are from areas with a high prevalence of tuberculosis, our renal transplant program, managed to reduce the rates of tuberculosis among recipients from 3.5% in the 1980s,[4] down to 0.5% among 1059 recipients of kidneys from living-related donors, after implementing living-donor screening. We also reduced the rate to zero cases among 177 recipients of kidneys from deceased donors after implementing universal isoniazid prophylaxis for this population in January 2008. Additionally, none of the recipients of kidney from deceased donors in 2013 and 2014 developed tuberculosis albeit the follow-up has been relatively short. We believe that a diligent search for LTBI in both recipients and living donors and offering isoniazid prophylaxis are the main reasons for reducing rates of tuberculosis in kidney transplant recipients in our center. We acknowledge that confounders may have influenced the rates of tuberculosis in renal transplant recipients, including a decline in tuberculosis in the general population, changes in the transplant donor and recipient population over time, changes in transplant immunosuppression, and improvement in the socioeconomics and health services with time. As reported by others, the use of "universal" isoniazid prophylaxis in living-related kidney transplantation in an endemic area resulted in reduced numbers of active tuberculosis after transplantation.[20-22]

WHO estimates the incidence rates of tuberculosis in Saudi Arabia to be 14 per 100 000 in 2013 (range, 12-16 per 100 000).[13] The prevalence of LTBI (defined as TST reaction of ≥10 mm) in the general population was reported in a nationwide survey in 1993 to be 33% in people without prior BCG vaccination.[23] The prevalence increases with age in BCG recipients to 70%. There are no new general population data on LTBI prevalence, but the incidence rate has decreased over the last ten years.[24] Nevertheless, the reduction in the incidence of tuberculosis in kidney recipients cannot be attributed to the incidence reduction in the general population alone. Compared to general population incidence rates of 2013, the incidence of tuberculosis in recipients of kidneys from a living-related donors is 8 times higher, in recipients of kidneys from deceased donors it is 14 times higher, in recipients of livers it is 42 times higher, in recipients of hearts it is 40 times higher, and in recipients of lungs it is 339 times higher. In the survival analysis, lung transplantation had significantly lower tuberculosis-free survival post transplantation (Log rank test $P<.0001$). The lung transplantation program is the smallest in terms of numbers (35 patients), and the two cases of tuberculosis were both donor related and diagnosed very early post-transplantation. One case was diagnosed by culture of *M tuberculosis* from the bronchoalveolar lavage in a post-transplant surveillance study. The second case was diagnosed from a nodule in the transplanted lung, which was excised and grew *M tuberculosis*. Both recipients did very well on tuberculosis chemotherapy and remain well. In a Spanish large cohort of SOT recipients and tuberculosis, 95% of patients with tuberculosis post-SOT were diagnosed within the first year. In our study, that proportion is 60%. Median time to develop post-SOT tuberculosis in the Spanish study was 183 days (range 28-499 days). In our study it was 9.2 months (range 1-70 months). Spanish recipients of lung transplantation had the highest rate and inci-

dence of tuberculosis.[8] Per 100 000 transplant-years, the incidence of tuberculosis in lung transplant recipients was 2072 cases in Spain, and 4750 in our cohort. For kidney recipients, the incidence rate in our cohort is 127 cases per 100 000 transplant-years compared to 358 in the Spanish cohort.[8] We believe the lower incidence rate in kidney recipients is related to the expanded isoniazid prophylaxis program.

Similar to other reports in the literature, the majority of tuberculosis cases in SOT recipients occurred within the first year post-transplantation. However, in our study, we noted the very low mortality rate (only one in 20 recipients or 5%) and for the non-tuberculosis cause. We believe this is related to early diagnosis and accumulating experience in managing tuberculosis in this population. **Table 4** summarizes the incidence of tuberculosis in SOT and mortality from selected reports and countries for comparison.

Finally, we believe that the low rates of tuberculosis in all organ groups and more specifically in the kidney transplantation group is related to the aggressive approach of prophylaxis and diagnosis of LTBI. Estimations of donor-derived tuberculosis at 5% of all tuberculosis in SOT are mainly from developed countries, where tuberculosis and LTBI rates are low. We think in developing countries and in Saudi Arabia the proportion of tuberculosis in SOT recipients that is donor-derived is higher. Therefore, preventive measures based on donor LTBI status will have more impact in reducing tuberculosis. Applying the expanded isoniazid prophylaxis to other organ groups (liver, heart, and lung) may not be equally feasible given the higher risks of hepatotoxicity especially in recipients of liver from deceased donors. Additionally, control measures of tuberculosis at community and health facility levels will reduce the risk of tuberculosis exposure and infection in solid-organ transplants. Continuous tuberculosis monitoring and future research into best ways to diagnose LTBI and identify potential recipients at highest risk of activation is needed.

Acknowledgments

We thank the Organ Transplant Center and Department of Infection Control and Hospital Epidemiology and their staff at King Faisal Specialist Hospital and Research Centre, Riyadh for support and cooperation.

REFERENCES

1. Munoz P, Rodriguez C, Bouza E. Mycobacterium tuberculosis infection in recipients of solid organ transplants. Clin Infect Dis 2005;40:581-587.
2. Lattes R, Radisic M, Rial M, Argento J, Casadei D. Tuberculosis in renal transplant recipients. Transpl Infect Dis 1999;1:98-104.
3. Malhotra KK, Dash SC, Dhawan IK, Bhuyan UN, Gupta A. Tuberculosis and renal transplantation—observations from an endemic area of tuberculosis. Postgrad Med J 1986;62:359-362.
4. Qunibi WY, al-Sibai MB, Taher S et al. Mycobacterial infection after renal transplantation--[g][h]report of 14 cases and review of the literature. Q J Med 1990;77:1039-1060.
5. Naqvi SA, Hussain M, Askari H et al. Is there a place for prophylaxis against tuberculosis following renal transplantation? Transplant Proc 1992;24:1912.
6. Hall CM, Willcox PA, Swanepoel CR, Kahn D, Van Zyl Smit R. Mycobacterial infection in renal transplant recipients. Chest 1994;106:435-439.
7. Singh N, Paterson DL. Mycobacterium tuberculosis infection in solid-organ transplant recipients: impact and implications for management. Clin Infect Dis 1998;27:1266-1277.
8. Torre-Cisneros J, Doblas A, Aguado JM et al. Tuberculosis after solid-organ transplant: incidence, risk factors, and clinical characteristics in the RESITRA (Spanish Network of Infection in Transplantation) cohort. Clin Infect Dis 2009;48:1657-1665.
9. Lopez de Castilla D, Schluger NW. Tuberculosis following solid organ transplantation. Transpl Infect Dis 2010;12:106-112.
10. Aguado JM, Torre-Cisneros J, Fortun J, Benito N, Meije Y, Doblas A, et al. Tuberculosis in solid-organ transplant recipients: consensus statement of the group for the study of infection in transplant recipients (GESITRA) of the Spanish Society of Infectious Diseases and Clinical Microbiology. Clin Infect Dis 2009;48:1276-1284.
11. Bumbacea D, Arend SM, Eyuboglu F et al. The risk of tuberculosis in transplant candidates and recipients: a TBNET consensus statement. Eur Respir J 2012;40:990-1013.
12. Subramanian AK, Morris MI. Mycobacterium tuberculosis infections in solid organ transplantation. Am J Transplant 2013;13 Suppl 4:68-76.
13. WHO. Tuberculosis Profile: Saudi Arabia. WHO, 2014. https://extranet.who.int/sree/Reports?op=Replet&name=/WHO_HQ_Reports/G2/PROD/EXT/TBCountryProfile&ISO2=SA&outtype=html. Accessed February 29, 2016.
14. Horne DJ, Narita M, Spitters CL, Parimi S, Dodson S, Limaye AP. Challenging issues in tuberculosis in solid organ transplantation. Clin Infect Dis 2013;57:1473-1482.
15. Holty JE, Sista RR. Mycobacterium tuberculosis infection in transplant recipients: early diagnosis and treatment of resistant tuberculosis. Curr Opin Organ Transplant 2009;14:613-618.
16. Subramanian A, Dorman S. Mycobacterium tuberculosis in solid organ transplant recipients. Am J Transplant 2009;9 Suppl 4:S57-62.
17. Edathodu J, Alrajhi A, Halim M, Althawadi S. Multi-recipient donor-transmitted tuberculosis. Int J Tuberc Lung Dis 2010;14:1493-1495.
18. Morris MI, Daly JS, Blumberg E et al. Diagnosis and management of tuberculosis in transplant donors: a donor-derived infections consensus conference report. Am J Transplant 2012;12:2288-2300.
19. Mycobacterium tuberculosis, in Guidelines for the Prevention and Management of Infectious Complications of Solid Organ Transplantation. Am J Transplant 2004;4 Suppl 10:37-41.
20. Naqvi R, Akhtar S, Noor H et al. Efficacy of isoniazid prophylaxis in renal allograft recipients. Transplant Proc 2006;38:2057-2058.
21. Naqvi R, Naqvi A, Akhtar S et al. Use of isoniazid chemoprophylaxis in renal transplant recipients. Nephrol Dial Transplant 2010;25:634-637.
22. de Lemos AS, Vieira MA, Halpern M et al. Results of implementation of preventive recommendations for tuberculosis after renal transplantation in an endemic area. Am J Transplant 2013;13:3230-3235.
23. A-Kassimi FA, Abdullah AK, al-Hajjaj MS, al-Orainey IO, Bamgboye EA, Chowdhury MN. Nationwide community survey of tuberculosis epidemiology in Saudi Arabia. Tuber Lung Dis 1993;74:254-260.
24. Abouzeid MS, Zumla AI, Felemban S, Alotaibi B, O'Grady J, Memish ZA. Tuberculosis trends in Saudis and non-Saudis in the Kingdom of Saudi Arabia--a 10 year retrospective study (2000-2009). PLoS One 2012;7:e39478.
25. Ergun I, Ekmekci Y, Sengul S et al. Mycobacterium tuberculosis infection in renal transplant recipients. Transplant Proc 2006;38:1344-1345.