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BRIEF COMMUNICATION

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Real-life food-safety behavior and incidence of foodborne infections in solid organ transplant recipients

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Food-safety measures are recommended in solid organ transplant (SOT) recipients. However, the actual adherence of patients in a real-life setting and the impact on the incidence of foodborne infections remain largely unexplored. We performed a survey among SOT recipients followed at our institution, aiming to evaluate their food-safety behavior. We assessed the incidence of microbiologically proven foodborne infections by chart review. One hundred ninety-seven SOT recipients (kidney = 117, lung = 35, liver = 29, and heart = 16) participated in the survey. Overall, 17.7% of the participants observed all food-safety recommendations (22.0% avoided food at risk of contamination while 67.9% applied hygiene recommendations). Patients within the first year after transplantation (odds ratio [OR] 5.42; *P* = .001) and females (OR 4.67; *P* = .001) followed food-safety recommendations more closely. Although the majority of SOT recipients felt concerned and actively sought information on food safety (68%-70%), only 27% were able to recognize all risks of foodborne infection in hypothetical scenarios. Incidence of proven foodborne infections was 17.9% (95% confidence interval 9.9%-30.9%) 5 years after transplantation. Importantly, foodborne infections occurred exclusively among patients not following food-safety recommendations. In summary, most SOT recipients eat foods that make them at risk of foodborne infections. Our results indicate that there is room for improvement in patient education, particularly later after transplantation, and reinforce current food-safety recommendations.

KEYWORDS

clinical research/practice, education, infection and infectious agents, infectious disease, organ transplantation in general, patient education, patient safety, survey

1 | INTRODUCTION

Solid organ transplant (SOT) recipients are at increased risk of infection due to lifelong immunosuppression. Beyond the early post-transplant course, once SOT recipients have reached a new steady state and resumed their everyday life, the majority of infections are community acquired.[1]

Among these infections, foodborne infections are frequent and may be caused by bacteria (including *Campylobacter*, *Salmonella*, *Shigella*, *Vibrio*, *Escherichia coli*, and *Listeria*), viruses (such as hepatitis A [HAV] and E viruses [HEV] or norovirus) and parasites (including *Giardia*, *Toxoplasma*, or tapeworms) transmitted by specific food

Abbreviations: HAV, hepatitis A virus; HEV, hepatitis E virus; OR, odds ratio; PCR, polymerase-chain reaction; SOT, solid organ transplant.

products.[2,3] Foods considered particularly at risk include raw/undercooked meat, fish or seafood, eggs or egg products, unpasteurized milk or dairy products, and some raw vegetables. Besides the consumption of those foods, the violation of hygiene and food-handling measures further increases the risk of foodborne infections. Accordingly, SOT recipients are generally educated on the risk of foodborne infections and on food-safety rules. It is recommended in international guidelines for SOT recipients to avoid the consumption of unpasteurized milk or unpasteurized milk byproducts (such as soft cheese), uncooked/raw meat, poultry, fish or seafood, as well as undercooked/raw eggs or their byproducts, and to follow strict adherence to hygiene and food-handling rules, such as hand washing, keeping cooked and raw food separated, and using separate or cleaned utensils for their preparation.[4] Although adherence to food-safety recommendations is probably variable in a real-life setting, only a few studies have assessed the rate of observance of food-safety recommendations by SOT recipients.[5,6]

We performed a survey among consecutive SOT recipients followed at our institution in order to describe their real-life food-safety behavior, their perception and knowledge of food safety, and we assessed the resulting incidence of foodborne infections.

2 | METHODS

2.1 | Study design and participants

This is a single-center survey aiming to describe the food-safety behavior of SOT recipients followed at our institution. Approximately 50 kidney, 15 heart, and 20 lung transplantations are performed each year at Lausanne University Hospital, and most of these patients are subsequently followed at the outpatient clinic of our institution. Liver transplantation is performed at Geneva University Hospital (within the Lausanne-Geneva Transplant Network), but patients are subsequently followed at our outpatient clinic (≈20 patients each year). All consecutive patients transplanted between January 2012 and June 2017 and regularly followed at Lausanne University Hospital were screened. Patients unable to correctly understand the survey due to insufficient knowledge of French or cognitive disorders were excluded. The survey, with the corresponding information letter and informed consent form, and a return envelope, was sent by postal mail in November 2017. Baseline characteristics and microbiologically proven episodes of foodborne infection from transplantation up to November 2017 were collected by chart review. *Campylobacter*, *Salmonella*, *Shigella*, enterotoxigenic, enteropathogenic and enterohemorrhagic *Escherichia coli*, *Vibrio*, *Yersinia*, *Listeria*, HAV and HEV, norovirus, *Giardia*, and tapeworms were considered foodborne infections. *Campylobacter*, *Salmonella*, *Shigella*, *E coli*, *Vibrio*, and *Yersinia* were detected by stool culture until May 2017 when polymerase-chain reaction (PCR) was introduced at our institution. Parasites were detected by stool examination or PCR after May 2017, and viruses by serology (HAV) or PCR (norovirus and HEV). Patients were tested for foodborne infection when clinically indicated as part of routine clinical practice.

Patients included in the survey were educated about food safety by nurses or physicians in charge at the time of transplantation or during follow-up visits as part of standard care. Routine education on food safety at our center includes the distribution of a booklet describing general hygiene rules for food handling, and specific oral education dispensed by caregivers about foods to avoid. No additional training or information was provided to caregivers or patients during the study period. The study protocol was approved by local Ethics Committee (project n° 2017-01625).

2.2 | Survey, definitions, and endpoints

We designed a survey based on existing questionnaires on food safety used in other populations of immunocompromised patients and on guidelines on food safety in SOT recipients.[4,7] The questionnaire was written in French. To reduce confirmation bias, we included in the survey questions about food, unrelated to food safety. The specific aim of the survey was unknown by the participants. An English translation of the survey is available in the Data S1. Briefly, besides questions on demographics (age, sex, education), the survey contained questions on (1) the consumption of 12 foods at risk of foodborne infection and the compliance with 4 hygiene and food-handling rules, (2) the information received and sought by patients about the importance of food-safety, and (3) patients' perception of the importance of food safety and the risk of infection. A 5-point Likert scale was used for all questions. Finally, patient's knowledge on food safety was tested in 6 hypothetical "at-risk" situations. In each situation, participants were asked to choose among 4 possible answers: 2 conducts (1 considered safe and the other unsafe), "I don't know," and "I would never be confronted with this situation." When the unsafe conduct was chosen or the participant did not know, the risk was considered not to be correctly identified.

The endpoint of the study was the observance of food-safety recommendations, defined as avoidance of foods at risk of foodborne infection and observance of hygiene and food-handling recommendations. Participants were considered (1) to observe food-avoidance recommendations if none of the foods were consumed more than "rarely" and (2) to observe hygiene recommendations if all hygiene rules were followed at least "most of the time."

2.3 | Statistical analysis

Descriptive statistics were used to illustrate patient's characteristics and survey answers. Univariate and multivariate logistic regression were used to identify variables associated with observance of food-safety measures. Variables included age, sex, high educational status (defined as high school or university completion), time after transplantation (≤1 or >1 year after

transplantation), and transplanted organ. Incidence of foodborne infection per 100 patient-years was calculated and cumulative incidence of documented foodborne infections was estimated with the Kaplan-Meier method. $P < .05$ was considered statistically significant. Analysis were performed using Stata software version 14 (Stata Corp LP, College Station, TX) and Graphpad Prism version 8.0.1 (La Jolla, CA).

3 | RESULTS

3.1 | Patients' characteristics

Three hundred ten consecutive transplant recipients, transplanted between January 2012 and June 2017 and meeting inclusion criteria, received the survey. A total of 197 SOT recipients (117 kidney, 35 lung, 29 liver, and 16 heart) returned the survey and were included in the study. Characteristics of the study population are described in Table 1. Median age was 58 years with a majority of men (62%). Participants were in median 2.7 years after transplantation. Sixteen percent (32/197) were within the first year after transplantation. The majority of patients (59%, 114/195) completed a technical school.

TABLE 1 Study population

Characteristics	N = 197
Median follow-up, y (IQR)	2.29 (1.24-3.75)
Age (y), median (IQR)	58 (48-65)
Sex (F/M)	74/123
Transplant, n (%)	
Heart	16 (8.1)
Liver	29 (14.7)
Lung[a]	35 (17.8)
Kidney	117 (59.4)
Second or retransplantation	14 (7.1)
Time after transplant in y, median (IQR)	2.67 (1.25-3.91)
≤1 y after transplantation	32 (16.2)
>1 y after transplantation	165 (83.8)
Maintenance immunosuppression, n (%)	
Tacrolimus	176 (89.3)
Cyclosporine	16 (8.1)
Mycophenolate	174 (88.3)
mTOR inhibitors	6 (3.1)
Azathioprine	15 (7.6)
Prednisone	135 (68.5)
Education[b], n (%)	
Mandatory school	37 (19.0)
Technical school	114 (58.5)
High school	21 (10.8)
University	23 (11.8)

IQR, interquartile range; mTOR, mammalian target of rapamycin.
[a]One combined lung-liver transplant.
[b]Missing for 2 patients.

3.2 | Food-safety behavior of SOT recipients

Overall, only 17.7% (33/186) of the evaluable participants were found to observe all food-safety recommendations as defined in this study (ie, never eat any food at risk more than rarely and observe all the hygiene recommendations at least most of the time). The frequencies at which study participants ate foods at risk of pathogen transmission and observed each food-handling and hygiene recommendation are detailed in Figure 1. Only 22.0% (40/182) never ate any of the foods at risk of contamination more than rarely. Participants who were found not to observe the food-avoidance recommendations ate in median 2 (IQR 1-4) different foods more than rarely. The most commonly consumed foods "at risk" were unpasteurized cheese (more than rarely by 46.6%), raw charcuterie (37.0%), meat cooked rare (30.8%), raw egg products (24.0%), and undercooked eggs (15.1%). However, the proportion of the participants who consumed those foods very often was low, ranging from 4.7% for unpasteurized cheese to 0.5% for undercooked eggs. By contrast, the majority of the participants (67.9%, 129/190) observed all food-handling and hygiene recommendations. Among those who did not adhere to all hygiene rules, a median of 3 hygiene rules (IQR 2-3) were observed.

3.3 | Variables associated with observation of food-safety recommendations

Transplantation during the previous year (odds ratio [OR] 5.42; 95% confidence interval [CI] 2.03-14.47; $P = .001$) and female sex (OR 4.67; 95% CI 1.88-11.6; $P = .001$) were associated with observance of food-safety recommendations in univariate and multivariate analysis (Table 2). In particular, avoidance of food at risk of contamination was more frequent in patients within the first year after transplantation (41.9% vs 17.8% in patients ≤1 year vs >1 year after transplantation, respectively; $P = .003$), in females (33.3% vs 15.0% in female vs male, respectively; $P = .004$), and in patients with higher educational status (33.3% vs 18.6% in higher vs lower educational status, respectively; $P = .043$). Observation of hygiene recommendations tended to be more frequent within the first year after transplantation (81.3% vs 65.2%, $P = .076$), and in females (74.6% vs 63.8%, $P = .124$), although the differences did not reach statistical significance.

3.4 | Information and perception on food safety and risk of infection in SOT recipients

Patients' information on food safety and their perception of food safety are illustrated in Figure 2. Overall, 22.6% (43/190) of the

Risk associated food*, %	Never	Rarely	Occasionally	Often	Very Often	Respected
Meat cooked rare	46.5	22.7	19.5	10.3	1.1	69.2
Undercooked poultry	82.7	11.5	4.7	1.1	0.0	94.2
Steak tartare	74.1	13.5	9.2	3.2	0.0	87.6
Raw charcuterie	33.3	29.7	27.1	8.3	1.6	63.0
Sushi	79.8	11.9	6.2	1.0	1.0	91.7
Ceviche	92	2.9	4.0	1.1	0.0	94.9
Raw shellfish	81.3	11.9	5.7	0.5	0.5	93.3
Undercooked eggs	60.9	24.0	11.5	3.1	0.5	84.9
Raw egg products	46.4	29.7	19.3	3.1	1.6	76.0
Raw milk	87.4	8.4	2.1	1.6	0.5	95.8
Non Pasteurized cheese	28.5	24.9	28.0	14.0	4.7	53.4
Raw been sprouts	77.7	16.1	4.7	1.6	0.0	93.8
Hygiene behavior, %**	**Never**	**Rarely**	**Occasionally**	**Most of the time**	**Always**	**Respected**
Visual meat inspection	1.6	3.7	2.1	37.4	55.1	92.5
Hand washing	2.1	0.5	6.2	40.0	51.3	91.3
Separation of raw foods	3.6	2.6	2.6	29.4	61.9	91.2
Separate utensils	9.3	4.7	8.3	22.8	54.9	77.7

FIGURE 1 Food-safety behavior of SOT recipients. Numbers represent the percentage of participants who consume each food and apply each hygiene rule according to frequency. Right column indicates the proportion of participants who observe each recommendation. Participants observing each food-safety recommendation are represented in different shades of green (darkening green with increasing percentage) and participants not observing the recommendation are represented in red, orange, and yellow according to the percentage. *At least 1 variable was missing for 43 patients ("ceviche" was missing in 22 patients). **At least 1 variable was missing for 12 patients. SOT, solid organ transplant

TABLE 2 Variables associated with observance of food-safety recommendations

	Univariate analysis		Multivariate analysis	
Variable	OR (95% CI)	*P*	OR (95% CI)	*P*
Age (y)	1.00 (0.98-1.03)	.762	1.01 (0.98-1.05)	.461
Sex (female)	2.79 (1.30-6.03)	.009	4.67 (1.88-11.61)	.001
Transplanted organ				
Heart vs kidney	2.53 (0.77-8.28)	.126	2.00 (0.51-7.90)	.321
Lung vs kidney	1.08 (0.39-2.99)	.877	0.89 (0.29-2.74)	.842
Liver vs kidney	0.84 (0.26-2.72)	.775	1.01 (0.28-3.68)	.990
Time after transplantation (≤1 y)	4.03 (1.71-9.49)	.001	5.42 (2.03-14.47)	.001
High educational status	1.96 (0.86-4.49)	.107	2.35 (0.92-6.01)	.073

participants estimated their risk of infection as high or very high and 37.4% (71/190) as low or absent. Most of the participants stated that they were informed at the time of transplantation about the importance of avoiding food at risk (82.9%, 160/193) and observing hygiene measures (88.6%, 171/193). Moreover, the majority stated that they informed themselves after transplantation about food avoidance (67.9%, 131/193) and hygiene measures (70.5%, 136/193). Accordingly, the majority of the study participants agreed that food behavior was important for reducing the risk of infection (88.7%, 172/194) and that their behavior contributed to reduce their specific risk of infection (85.6%, 166/194).

3.5 | Hypothetical "real-life" situations

Six hypothetical real-life situations in the survey tested the attitude to cope with (1) contamination of salad with raw poultry, (2) contamination of cutting board with raw poultry before use, (3) raw fruit, (4) left-over food in the refrigerator, (5) undercooked meat served in a restaurant, and (6) dessert prepared with raw eggs served at a friend's home (Figure 3). Overall, only 27.3% (51/187) of the participants were always able to identify the risk of foodborne infection in all 6 situations. Participants within the first year after transplantation were more likely to identify the risk of food contamination (51.6% vs 22.4%

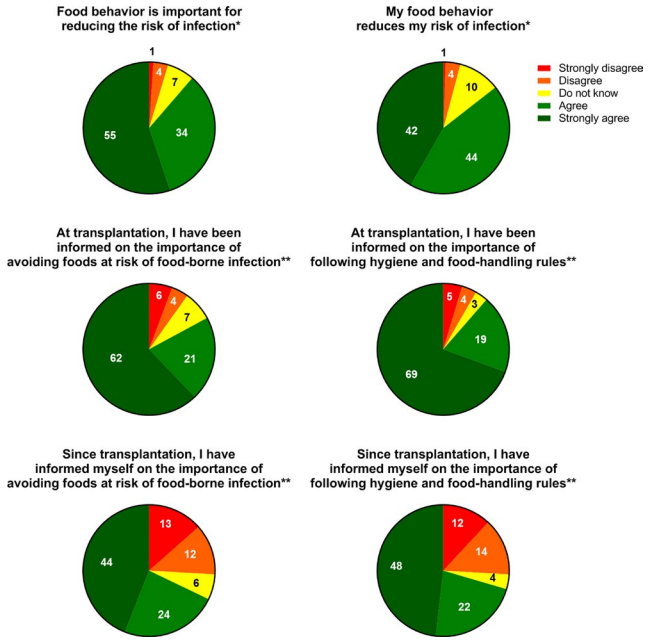

FIGURE 2 SOT recipients' information and perception on food safety and risk of infection. Numbers represent the percentage of patients according to agreement degree to each statement (red = strongly disagree, orange = disagree, yellow = do not know, green = agree, and dark green = strongly agree). *Answers were missing for 3 patients. **Answers were missing for 4 patients. SOT, solid organ transplant

identified all the risk of foodborne infection among patients ≤1 year vs patients >1 year after transplantation, respectively, $P = .001$).

3.6 | Microbiologically proven foodborne infections

In our cohort, microbiologically confirmed foodborne infections occurred in 16 (8%) patients (4 *Campylobacter* gastroenteritis, 1 *Salmonella* bacteremia with septic arthritis, 3 HEV, and 8 norovirus infections) at a median of 1.49 (IQR 0.79-3.38) years after transplantation. The calculated incidence per 100 person-years was 0.8 (95% CI 0.3-2.1) for *Campylobacter*, 1.6 (95% CI 0.8-3.2) for norovirus, and 0.6 (95% CI 0.2-1.8) for HEV. Incidence of foodborne infection was 17.9% (95% CI 9.9%-30.9%) at 5 years after transplantation (Figure 4). Hospital admission was required for 6/16 episodes and specific antibiotic treatment for all bacterial infections. Two of 3 HEV developed a chronic infection, although virus clearance was finally achieved in all patients (1 required treatment with ribavirin). None of the patients with documented foodborne infection was found to observe food safety (0/33 vs 16/153 foodborne infections among patients observing and not observing food safety, respectively; $P = .052$).

4 | DISCUSSION

In this survey of 197 SOT recipients followed at our institution, we found that only 17.7% of the participants observed all food-safety recommendations. This result was principally driven by the low rate of compliance with food avoidance recommendations (22%). Although in agreement with current guidelines,[4] the criteria used in this survey to comply with food avoidance recommendations were particularly stringent (ie, never eat any of the foods at risk more than rarely). Despite the fact that few patients followed all recommendations, the number of foods at risk of contamination consumed by each participant, and the proportion of patients consuming at-risk foods very often, were low. Collectively, the results suggest that the majority of SOT recipients in our study population occasionally consume 1 food at risk, rather than having a thoughtless high-risk behavior, reflecting the normal life lived by our patients after successful transplantation.

Few data are available regarding the real-life food-safety behavior of SOT recipients. In a survey performed among lung transplant recipients in Canada, 52% of the patients rarely consumed unpasteurized cheese and the majority (85%-93%) avoided undercooked or raw meat, eggs and poultry, and unpasteurized dairy products.[5] In another small study including 19 SOT recipients, participants frequently ate soft cheese (67%) and raw eggs (33%), but observed hygiene rules (89%-72%).[6]

At our institution, education about food safety includes a written brochure distributed to all SOT recipients at transplantation and containing general information on hygiene and food handling rules. Additional specific education on foods avoidance is provided by nurses and physicians at transplantation and during follow-up visits, which may vary according to the transplant program. Despite this, we did not find any difference in patients' behavior according to the transplanted organ. The results of the survey will foster the harmonization of our educational program by providing specific food-avoidance written recommendations. We also found that the early posttransplant period (up to 1 year after transplantation) was associated with observance of recommendations and better knowledge of food safety, probably because more emphasis is given about food safety during this period. Accordingly, written standardized information and a systematic reminder at 1 year after transplantation may be worth consideration by transplantation centers likely to have similar gaps in their educational program.

In our cohort, we found a high incidence of microbiologically proven foodborne infections (18% at 5 years). Since it is not exclusively a foodborne disease, norovirus infections may contribute to overestimating the incidence of foodborne infections (incidence of 8.3% when excluding norovirus). On the other hand, as we collected only microbiologically proven infections, some mild and self-resolving episodes of infections may have been undiagnosed because the patients did not seek medical attention. Despite a diagnostic bias towards enhanced testing in SOT recipients, we observed an incidence of *Campylobacter* infections 8-40 times higher than the general population (19.6-100 cases per 100 000 persons per year in the general population).[3,8] The proportion of HEV reflects the endemic situation in Switzerland (seroprevalence of 20% among blood donors).[9] In studies addressing the cause of diarrhea in SOT recipients, the proportion of foodborne infections varied, ranging between 1% and 30% for *Campylobacter* and *Salmonella* and 4% and 26% for

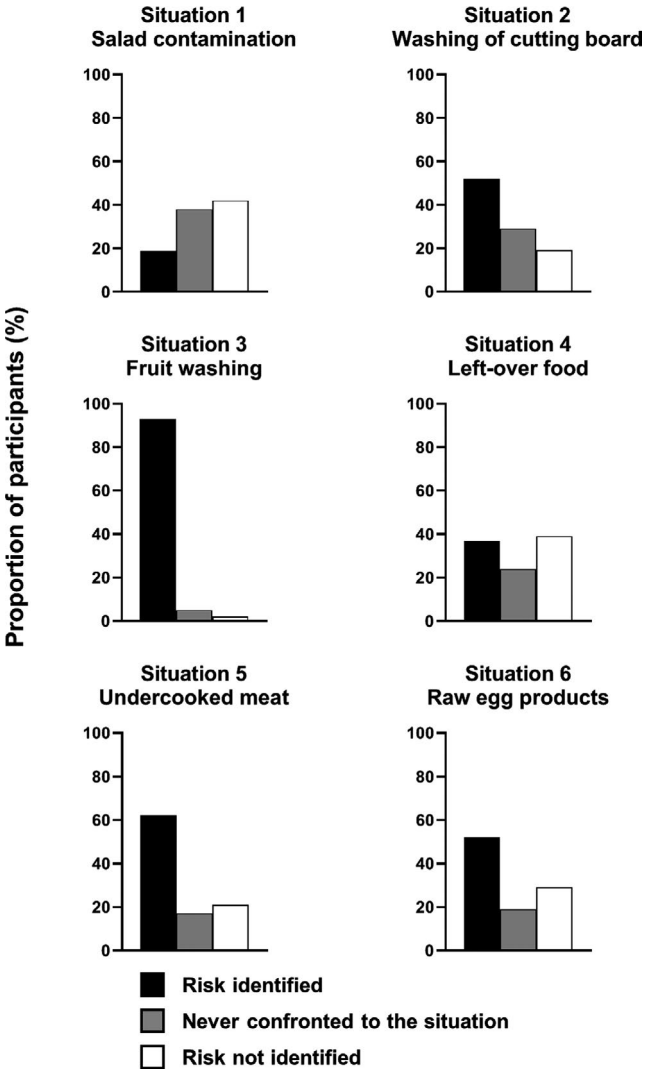

FIGURE 3 SOT recipients' behavior in regard to hypothetical real-life situations carrying a risk of foodborne infection. Proportion of participants who chose the correct answer (black bars), who would never be confronted by the situation (gray bars), and who did not know or chose the wrong answer (white bars) are represented. Answers were missing for 2 (situations 1 and 3), 5 (situation 2), and 4 (situations 4, 5, and 6) participants

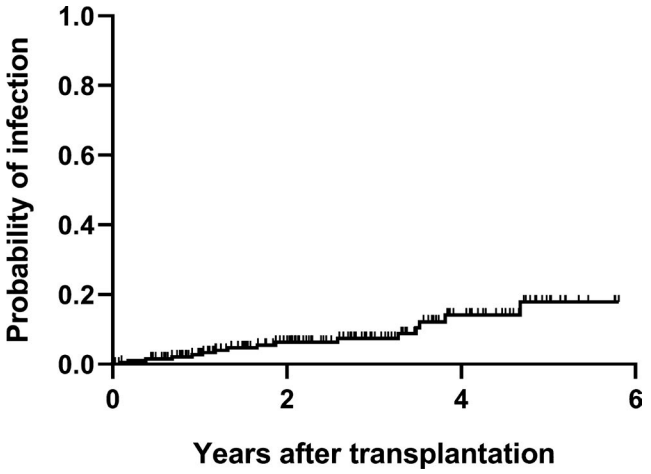

FIGURE 4 Incidence of microbiologically proven foodborne infections in the study population assessed by Kaplan-Meier method

norovirus, although few studies systematically assessed the epidemiology of foodborne infections in SOT recipients.[10-13] We observed 1 case of severe invasive bacterial foodborne infection and 2 cases of chronic HEV infection, which are known severe complications in SOT recipients.[14-16] Nevertheless, the precise impact of foodborne infections on graft and patient outcomes is not well described.[17]

Foodborne infections exclusively occurred among patients not observing food-safety recommendations. Recommendations are largely based on expert opinions and "common-sense approaches" resulting from knowledge of epidemiology and mechanism of transmission of infections, rather than on scientific evidence of an impact in reducing the rate of foodborne illnesses or improving patient and graft survival.[4] Although our study was neither designed nor powered to answer this question, our results seem to reinforce current recommendations.

Some limitations of our study need to be acknowledged. First, generalization of findings on food-safety behavior may be limited by the influence of cultural norms on food habits (which may change across different countries) and by variation in educational programs between transplantation centers. Accordingly, multinational studies including centers belonging to different geographical and cultural areas should be performed in order to confirm our preliminary results. Second, the interpretation of the questionnaire might have been variable between participants. Finally, patients not concerned about food safety, with lower educational status or knowledge of French may be underrepresented in our study population. The strengths of our study are the inclusion of a large number of participants (68% of the eligible patients) and the comprehensive approach to food safety, an unexplored area of research, including detailed data about specific food consumption and hygiene practices, patient's viewpoint, and epidemiology of infections. In addition, the scope of the survey was unknown to the participants and questions unrelated to food safety were inserted in the survey in order to minimize bias.

In conclusion, we report that the majority of SOT recipients do not systematically follow food-safety recommendations, particularly beyond the first year after transplantation, as they occasionally consume at-risk foods. Overall, our results tend to reinforce current guidelines and suggest that educational effort should be made to improve patients' compliance with food-safety measures. The generalizability of our findings and whether a better adherence to these measures would result in a reduction of foodborne infections and improved graft and patient survival are issues that need to be further assessed in multinational studies.

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DISCLOSURE

The authors of this manuscript have no conflicts of interest to disclose as described by the *American Journal of Transplantation*.

AUTHOR CONTRIBUTION

ML was involved in study design, data collection and analysis. OM and MM were involved in study design and data analysis. LvdB was involved in data collection. All authors contributed to data interpretation and writing of the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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