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TRANSPLANT INFECTIOUS DISEASE

ORIGINAL ARTICLE

The impact of preservation fluid culture on graft site arteritis: A systematic review and meta-analysis

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Abstract

Background: The role of culturing the graft preservation fluid (PF) is controversial and its impact on graft arteritis development remains unclear.

Methods: Systematic literature search retrieving observational studies comparing solid organ transplant (SOT) recipients with culture-positive PF versus culture-negative PF. The quality of included studies was independently assessed according to the ROBINS-I tool for observational studies. Meta-analysis was performed using Mantel-Haenszel random-effect models. Graft site arteritis within 180 days from transplant was selected as the primary outcome.

Results: Twenty-one observational studies (N = 2208 positive PF vs. 4458 negative) were included. Among positive PF, 857 (38.8%) were classified as high-risk group pathogens and 1351 (61.2%) as low-risk pathogens. Low-risk and negative PF showed similar odds ratios. A significant higher risk of graft arteritis was found in SOT recipients with a PF yielding a high-risk pathogen (odds ratio [OR] 18.43, 95% confidence interval [CI] 7.83–43.40) compared to low-risk and negative PF, with low heterogeneity (I^2 = 2.24%). Similar results were found considering separately high-risk bacteria (OR 12.02, 95%CI 4.88-29.60) and fungi (OR 71.00, 95%CI 28.07–179.56), with no heterogeneity (I^2 = 0%), and in the subgroup analyses of the liver (OR 16.78, 95%CI 2.95–95.47) and kidney (OR 19.90, 95%CI 4.78–82.79) recipients. However, data about diagnostic features of graft arteritis were very limited, indeed for only 11 of the 93 events histological or microbiological results were reported.

Conclusions: Our results may support the performance of PF culturing and a pre-emptive diagnostic or therapeutic management upon isolation of high-risk pathogens. Further studies based on a reliable diagnosis of graft arteritis are needed.

KEYWORDS
preservation fluid, mycotic aneurism, graft arteritis, solid organ transplantation

List of Abbreviations: CI, confidence interval; PF, preservation fluid; KT, kidney transplantation; LT, liver transplantation; SOT, solid organ transplantation; CoNS, coagulase-negative staphylococci; OR, odds ratio.

1 | INTRODUCTION

The performance and interpretation of cultures of preservation fluid (PF) in the prevention of donor-derived infections is still a controversial issue. Several reports have underlined the association between fungal isolation from PF cultures and the development of graft arteritis after kidney transplantation (KT). However, they consisted of small outdated retrospective series.[1–3] Based on that reports, guidance documents recommend antifungal pre-emptive treatment in patients undergoing abdominal transplants with evidence of fungal isolation from PF. However, the association between bacterial isolation from PF and the development of graft arteritis has not been established yet, thus the management of patients receiving grafts with bacterial growth from PF remains an unmet clinical need. With these assumptions, we aimed to perform a systematic review in order to explore the impact of positive PF on graft-site arteritis in the solid organ transplant (SOT) population.

2 | MATERIALS AND METHODS

A systematic review and meta-analysis investigating the development of graft site arteritis in SOT recipients with positive graft PF compared to negative were performed. The meta-analysis was registered in the PROSPERO database, number CRD42021291329, and was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines.[4]

2.1 | PECO question

P SOT recipients, including liver, kidney, heart, lung, and combined transplant.

E Cases with positive PF. According to previous studies,[5,6] we categorized microorganisms retrieved from PF as "high-risk" pathogens including gram-negative bacilli, Staphylococcus aureus, β-hemolytic streptococci, Streptococcus pneumoniae, Enterococcus spp., any spore-forming anaerobic gram-positive bacteria, Bacteroides spp., and Candida spp., and as "low risk," including coagulase-negative staphylococci (CoNS), Corynebacterium spp., viridans group streptococci group and all the other culture-positive PF.

C Cases with negative PF.

O Graft arteritis within 180-day from transplant.

2.2 | Literature search

Two authors (Matteo Rinaldi and Cecilia Bonazzetti) independently searched PubMed-MEDLINE, EMBASE, and Scopus databases from inception to 15 December 2021. The following search string was developed: ("SOT" OR "solid organ transplantation" OR "kidney transplant" OR "KT" OR "liver transplant" OR "liver transplantation (LT)" OR "heart transplant" OR "heart transplantation" OR "lung transplant" OR "lung transplantation") AND ("positive PF" OR "PF" OR "positive preservation solution" OR "preservation solution" OR "positive preservative solution" OR "preservative solution" OR "positive donor cultures" OR "donor cultures" OR "positive preservative liquid" OR "preservative liquid" OR "negative PF" OR "negative preservation solution" OR "negative preservative solution" OR "negative preservation liquid" OR "negative preservative liquid" OR "graft arteritis" OR "site graft arteritis" OR "mycotic aneurism" OR "candida arteritis"). Identified records were divided into two equal groups, and two pairs of authors (Matteo Rinaldi and Milo Gatti, Cecilia Bonazzetti and Natascia Caroccia) independently searched a predefined group for the removal of duplicates. Reference lists of included studies were screened to identify any potentially relevant articles.

2.3 | Study selection

Prospective/retrospective observational studies, published in all languages, comparing graft arteritis in SOT recipients with positive versus negative preservative fluid cultures were included. Studies were excluded if no comparator group was provided, or quantitative target outcome results were lacking. For studies using the same SOT registry as the data source, the report with the largest number of patients was considered. Additionally, conference abstracts and case reports/series were not eligible.

The primary outcome was the development of graft site arteritis within 180 days from transplant in each of the two groups (positive graft PF vs. negative).

Two pairs of authors (Matteo Rinaldi and Milo Gatti, Cecilia Bonazzetti and Natascia Caroccia) independently screened titles and abstracts of each predefined group of records for potential relevance and assessed the eligibility of relevant full texts. Any disagreement was resolved by means of discussion or consultation with a third reviewer (Maddalena Giannella).

2.4 | Data extraction

Two pairs of authors (Matteo Rinaldi and Milo Gatti, Cecilia Bonazzetti and Natascia Caroccia) independently extracted data from each included study retrieved in the assigned group in a pre-specified form. The following data were extracted: a) study author and year of publication and country in which the study was conducted; b) study characteristics including study design, time period, sample size, exclusion criteria, and funding; c) features of the recipients including age, sex, type of SOT, immunosuppressive treatment at baseline, any adjustment in immunosuppressive treatment; d) donor characteristics including sex and age, duration of ischemia, results of blood, urine, respiratory samples, and of graft PF cultures; e) diagnosis of graft site arteritis within 180 days from transplantation, therapeutic management, graft loss, and 180-day mortality.

Corresponding authors of publications that reported unclear data that may lead to misinterpretations were contacted by email for

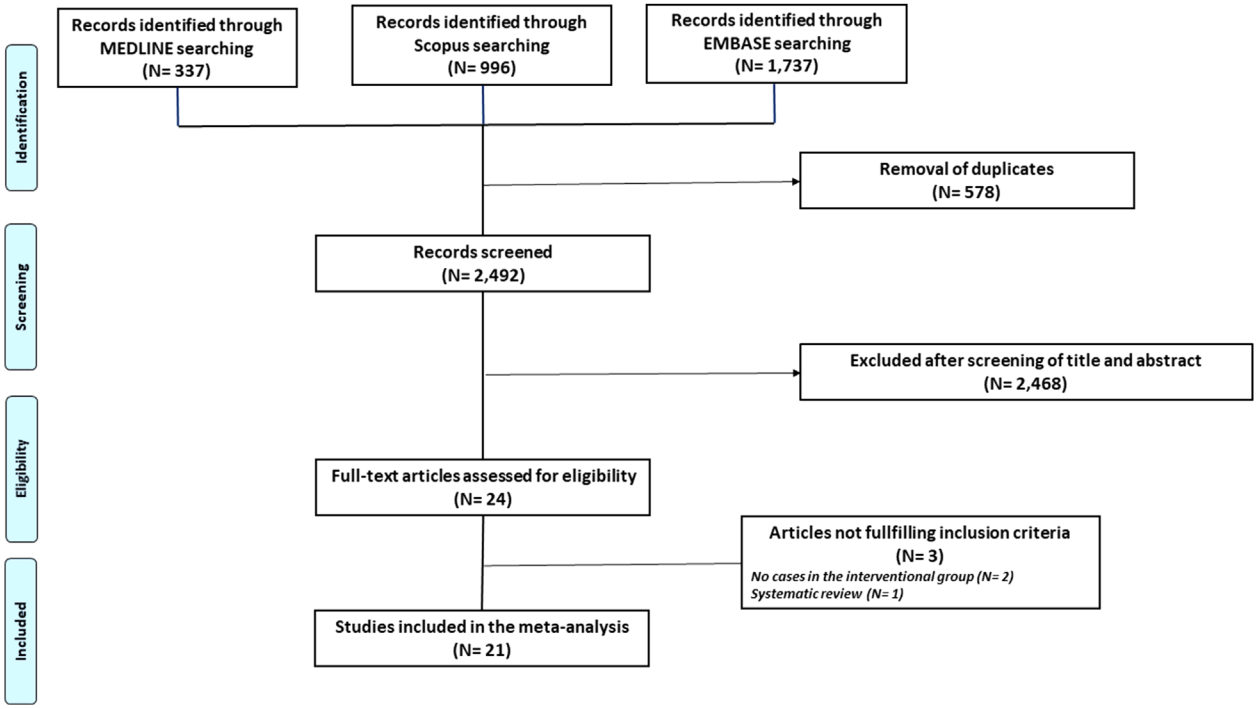

FIGURE 1 PRISMA flow diagram for study selection

clarification and/or for requesting supplemental information on the included studies.

2.5 | Risk of bias assessment

Two authors (Matteo Rinaldi and Cecilia Bonazzetti) independently assessed the risk of bias in the included studies. The Risk Of Bias In non-randomized studies of interventions (ROBINS-I)[7] was used to assess the risk of bias. Any disagreement was resolved by means of discussion or consultation with a third reviewer (Maddalena Giannella).

2.6 | Data analysis

Treatment effects were calculated as odds ratio (OR), with a 95% confidence interval (CI) for dichotomous data, by using a random-effect model with the inverse variance method. Statistical heterogeneity among studies was assessed by χ^2 test ($p<0.10$ indicated significant heterogeneity) and I^2 (degree of heterogeneity). An I^2 of >50% was considered indicative of substantial heterogeneity. Subgroup analysis was performed according to the type of pathogen retrieved from PF cultures among high-risk pathogens (bacterial or fungal isolates) and to the type of SOT (liver or kidney transplant). Sensitivity analyses were also conducted by excluding each study ("leave-one-out" approach) in order to investigate the confidence of the outcomes. Publication bias was assessed by visual inspection of the funnel plot and Egger's test.[8]

Statistical analysis was performed using MedCalc for Windows (MedCalc statistical software, version 19.6.1, MedCalc Software Ltd, Ostend, Belgium).

3 | RESULTS

The electronic and manual search identified 3070 potential studies, and among these 578 were removed as duplicates. After an initial screening of titles and abstracts, 2468 studies were excluded. Overall, 24 full-text articles were assessed for eligibility, and finally, 21 studies met the inclusion criteria. Three studies were excluded according to the following criteria: no cases in the exposure group (two studies); systematic review (one study; Figure 1).

3.1 | Characteristics of the included studies

Features of the 21 included studies are shown in Table 1. Overall, 6666 SOT patients were included (2208 with positive PF vs. 4458 negative PF). In three studies,[9–11] the comparator group was considered only as negative for fungal pathogens, thus they were excluded from the overall analysis and included in the subgroup analysis. Seven studies were prospective and 14 were retrospective.[5,6,9–27] Fifteen studies were conducted in Europe, three in Northern America (two in the USA and one in Canada), two in South America (Brazil and Argentina), and one in Asia. The mean or median patient age was 53.5 vs. 50.1 years, and males were 62% vs. 54% in the exposed and comparator groups, respectively.

TABLE 1 Principal characteristics of included studies

Study reference	Study design	Country	Time period	No. of enrolled SOT (pos PF vs. neg)	Age (mean or median)	Sex (Male)	Exposed group (PF culture positive)			Comparator group (PF culture negative)		
							Liver	Kidney	Arteritis	Liver	Kidney	Arteritis
Cerutti et al.	Retrospective observational	Italy	Jan 1998–Dec 2002	157 versus 453	54 versus 51	45.0% versus 57.0%	157	0	0	453	0	1
Sauget et al.	Retrospective observational	France	Jan 2007 – Jan 2010	72 versus 60	NA	NA	0	72	0	0	60	0
Stern et al.	Retrospective observational	Germany	Jan 2008 – Jan 2019	26 versus 2495*	47.5 versus NA	57.0% versus NA	15	11	2	1233*	1262*	0
Rodrigues et al.	Prospective observational	Portugal	Jun 2010 – Set 2011	6 versus 64*	49 versus NA	50.0% versus NA	0	6	2	0	64*	0
Garcia-Zamora et al.	Retrospective observational	Spain	Dec 2010 – Aug 2014	79 versus 99	NA	NA	79	0	0	99	0	0
Levesque et al.	Retrospective observational	France	Jan 2008 – Dec 2012	28 versus 2079	57 versus NA	75.0% versus NA	28	0	8	2079	0	0
Oriol et al.	Prospective observational multicentric	Spain	Jul 2015 – Mar 2017	389 versus 233	NA	NA	NA	NA	1	NA	NA	0
Reticker et al.	Retrospective observational	USA	Jan 2015 – Dec 2017	102 versus 50	49.4 versus 50.7	64.8% versus 62.0%	0	102	0	0	50	0
Ruiz et al.	Prospective observational	Spain	Mar 2007 – Mar 2008	59 versus 1	61 versus 59	NA	59	0	0	1	0	0
Yu et al.	Retrospective observational	China	Oct 2010 – Mar 2018	776 versus 226	NA	NA	0	776	78	0	226	0
Audet et al.	Prospective observational	France	Jan 2005 – Jun 2007	91 versus 141	NA	NA	91	0	0	141	0	0
Battaglia et al.	Retrospective observational	Italy	Jan 1999 – Jan 2003	12 versus 148	NA	NA	0	12	4	0	148	0

(Continues)

TABLE 1 (Continued)

Study reference	Study design	Country	Time period	No. of enrolled SOT (pos PF vs. neg)	Age (mean or median)	Sex (Male)	Exposed group (PF culture positive)			Comparator group (PF culture negative)		
							Liver	Kidney	Arteritis	Liver	Kidney	Arteritis
Veroux et al.	Retrospective observational	Italy	Jan 2008 – Jan 2010	24 versus 38	52.4 versus 47.9	50.0% versus 34.2%	0	24	0	0	38	0
Grat et al.	Prospective observational	Poland	Dec 2010 – Sep 2011	39 versus 6	54.5 versus 43	54.3% versus 33.3%	39	0	0	6	0	0
Janny et al.	Prospective observational	France	Jan 2001 – Jan 2008	45 versus 432	58 versus 49	82.0% versus 70.0%	45	0	0	432	0	0
Chaim et al.	Retrospective observational	Brazil	Jan 2000 – Dec 2008	15 versus 106	NA	NA	15	0	0	106	0	0
Yansouni et al.	Retrospective observational	Canada	Jul 2006 – Jan 2009	206 versus 125	53.5 versus 52.3	65.8% versus 67.6%	69	105	0	25	78	0
Reimondez et al.	Prospective observational	Argentina	Jan 2014 – Dec 2017	33 versus 55	52 versus 48	75.8% versus 56.4%	33	0	0	55	0	0
Nam et al.	Retrospective observational	USA	Nov 2013 – Nov 2014	43 versus 26	NA	NA	NA	NA	0	NA	NA	0
Botterel et al.	Retrospective observational	France	Jan 2004 – Dec 2008	21 versus 638*	NA	NA	10	11	0	252*	386*	0
Wakelin et al.	Retrospective observational	UK	Jan 1999 – Dec 2002	38 versus 180	NA	NA	0	38	0	0	180	0

All studies involved liver and kidney transplant recipients, in one study 31 pancreas and 11 heart transplant recipients were also enrolled.

A description of pathogens isolated from PF is shown in Table 2. Among positive PF, 857 (38.8%) were classified as a high-risk group and 1351 (61,2%) as low-risk. Briefly, high-risk group consisted of Gram-negative bacteria, $n = 625$; Gram-positive bacteria, $n = 399$ (mainly *Enterococcus* spp. $n = 292$); and fungi, $n = 290$. Coagulase-negative Staphylococci ranked first among a low-risk group, $n = 1060$ cases. Polymicrobial PFs were considered as a single PF and classified on the basis of pathogenicity (i.e., PF with concomitant high-risk and low-risk pathogens considered as a unique high-risk PF).

3.2 | Outcome assessment

A total of eighteen studies (2208 positive PF vs. 4458 negative PF) provided data for graft site arteritis rate.[5,6,12–27] Overall, 96 SOT recipients (kidney $n = 80$, liver $n = 16$) were diagnosed of graft arteritis. In all but one, the culture of PF was obtained as positive. In all patients with positive PF, concordance between pathogens retrieved from PF and those isolated from graft arteritis was reported. However, further data about histological and microbiological diagnostic findings of graft arteritis were missed for the majority of cases, with only six events supported by both histology and culture results, and another five with positive intra-operative cultures of the arterial graft anastomosis (Table S2).

Odds ratios of patients receiving a PF yielding a low-risk pathogen were similar to the negative group (OR 0.13, 95%CI 0.04–0.41 vs. 0.39, 95%CI 0.003–0.44, respectively) (Table 2). High degree of heterogeneity was observed in both analysis ($I^2 = 80.03\%$, $p = 0.001$ and $I^2 = 69.70\%$, $p = 0.01$). The funnel plot and Egger's test ($p = 0.053$ and $p = 0.31$) did not show evidence of publication bias. Therefore, the meta-analysis was further carried out considering both low-risk and negative PF as a unique comparator group (857 high-risk PF vs. 1351 low-risk/negative PF) as shown in Table 3. Overall, SOT recipients with a PF yielding a high-risk pathogen showed a significantly increased risk of arteritis development compared to low-risk/negative PF (OR 18.43; 95%CI 7.83–43.40; Figure 2). No heterogeneity was observed ($I^2 = 2.24\%$, p = 0.43). The funnel plot and Egger's test (p = 0.001) showed possible evidence of publication bias.

3.3 | Subgroup analysis

3.3.1 | Graft site arteritis development in high-risk versus low-risk/negative bacterial group

A total of seventeen studies (632 high-risk PF vs. 3,730 low-risk/negative PF) were included in this subgroup analysis.[5,6,9–12,14,15,18,20–23,26,27] SOT recipients with a PF yielding high-risk bacteria showed a significantly increased risk of arteritis development compared to low risk/negative PF (OR 12.02; 95%CI 4.88–29.60; Figure 3). No heterogeneity was observed ($I^2 = 0\%$, p = 0.99). The funnel plot and Egger's test (p = 0.01) showed possible evidence of publication bias.

3.3.2 | Graft site arteritis development in a fungal high-risk group

A total of 15 studies (290 fungal PF vs. 7225 low-risk/negative PF) were included in this subgroup analysis.[5,6,9–12,14,15,18,20–23,26,27] SOT recipients with a PF yielding a fungal organism showed a significantly increased risk of arteritis development compared to low-risk/negative PF (OR 71.00, 95%CI 28.07–179.56; Figure 4). No heterogeneity was observed ($I^2 = 0\%$, $p = 0.43$). The funnel plot and Egger's test ($p = 0.002$) showed possible evidence of publication bias.

3.3.3 | Graft site arteritis development according to the type of SOT

A total of eight studies (154 high-risk PF vs. 3620 low-risk/negative PF) provided data for graft site arteritis rate among liver recipients.[12,14,15,19,22–25] Liver recipients with a PF yielding a high-risk pathogen showed a significantly increased risk of arteritis development compared to low-risk/negative PF (OR 16.78, 95%CI 2.95–95.47; Figure 5 panel a). However, moderate degree of heterogeneity was observed ($I^2 = 43.47\%$, $p = 0.09$). The funnel plot and Egger's test ($p = 0.08$) did not show evidence of publication bias.

A total of six studies (443 high-risk PF vs. 1283 low-risk/negative PF) provided data for graft site arteritis rate among kidney recipients.[13,16,18,20,21,26] Renal recipients with a PF yielding a high-risk pathogen showed a significantly increased risk of arteritis development compared to low-risk/negative PF (OR 19.90, 95%CI 4.78–82.79; Figure 5 panel b). No heterogeneity was observed ($I^2 = 0\%$, p = 0.74). The funnel plot and Egger's test (p = 0.008) showed possible evidence of publication bias.

3.4 | Sensitivity analysis

In the "leave-one-out analysis", the sequential exclusion of every single study had no impact on the primary outcome of graft arteritis development.

3.5 | Quality of the included studies

Among included studies, 15 out of the 21 included studies showed a serious risk of bias in at least one domain, being biased due to confounding the most reported. Six studies were classified as being at moderate risk of bias, while none of the included observational studies exhibited a low risk of bias (Table S1).

TABLE 2 Distribution of micro-organisms yielded from preservation fluids and relative odds ratios

High risk PF ($N = 857$)										
	Gram-positive $N = 399$			Gram-negative $N = 625$			Fungi	Graft arteritis	Odds ratio (95% CI)	Heterogeneity (I^2; p-value)	Publication bias (p-value Egger's test)
No. of studies	*S. aureus*	*Enterococcus* spp.	*S. B-haemolyticus*	Enterobacteriaceae	*Pseudomonas* spp.	Anaerobic bacilli					
18	89	292	18	282	43	300	290	95	18.43 (7.83–43.40) $p < 0.001$	2.24% $p = 0.43$	$p = 0.001$
Low-risk PF ($N = 1351$)											
	Gram-positive $N = 1185$					Other		Graft arteritis	Odds ratio (95% CI)	Heterogeneity (I^2; p-value)	Publication bias (p-value Egger's test)
No. of studies	CoNS	*Corynebacterium* spp.	*S. viridans*	*Propionibacterium* spp.							
18	1060	36	53	36		151		0	0.13 (0.04– 0.41) $p < 0.001$	80.03% $p = 0.001$	$p = 0.052$
Negative PF (N = 4,458)											
No. of studies								Graft arteritis	Odds ratio (95% CI)	Heterogeneity (I^2; p-value)	Publication bias (p-value Egger's test)
18								1	0.39 (0.003–0.44) $p = 0.008$	69.70% $p = 0.01$	$p = 0.31$

TABLE 3 Results of meta-analysis for the primary outcome and subgroup analysis

Outcome	Studies	No. of PF (high-risk overall vs. low-risk/ negative)	No. of events in the intervention group	No. of events in the comparator group	Odds ratio (95% CI)	Heterogeneity (I^2; p-value)	Publication bias (p-value Egger's test)
Graft arteritis development	18	857 versus 5809	93/857	1/5809	18.43 (7.83–43.40) $p < 0.001$	2.24% $p = 0.43$	0.001
Outcome	**Studies**	**No. of PF (high-risk bacteria vs. low-risk/ negative)**	**No. of events in the intervention group**	**No. of events in the comparator group**	**Odds ratio (95% CI)**	**Heterogeneity (I^2; p-value)**	**Publication bias (p-value Egger's test)**
Graft arteritis development	17	632 versus 3730	49/632	1/3730	12.02 (4.88–29.60) $p < 0.001$	0% $p = 0.99$	0.01
Outcome	**Studies**	**No. of PF (positive for fungi vs. low risk/ negative)**	**No. of events in the intervention group**	**No. of events in the comparator group**	**Odds ratio (95% CI)**	**Heterogeneity (I^2; p-value)**	**Publication bias (p-value Egger's test)**
Graft arteritis development	15	290 versus 7225	48/290	0/7225	71.00 (28.07–179.56) $p < 0.001$	0% $p = 0.43$	0.002

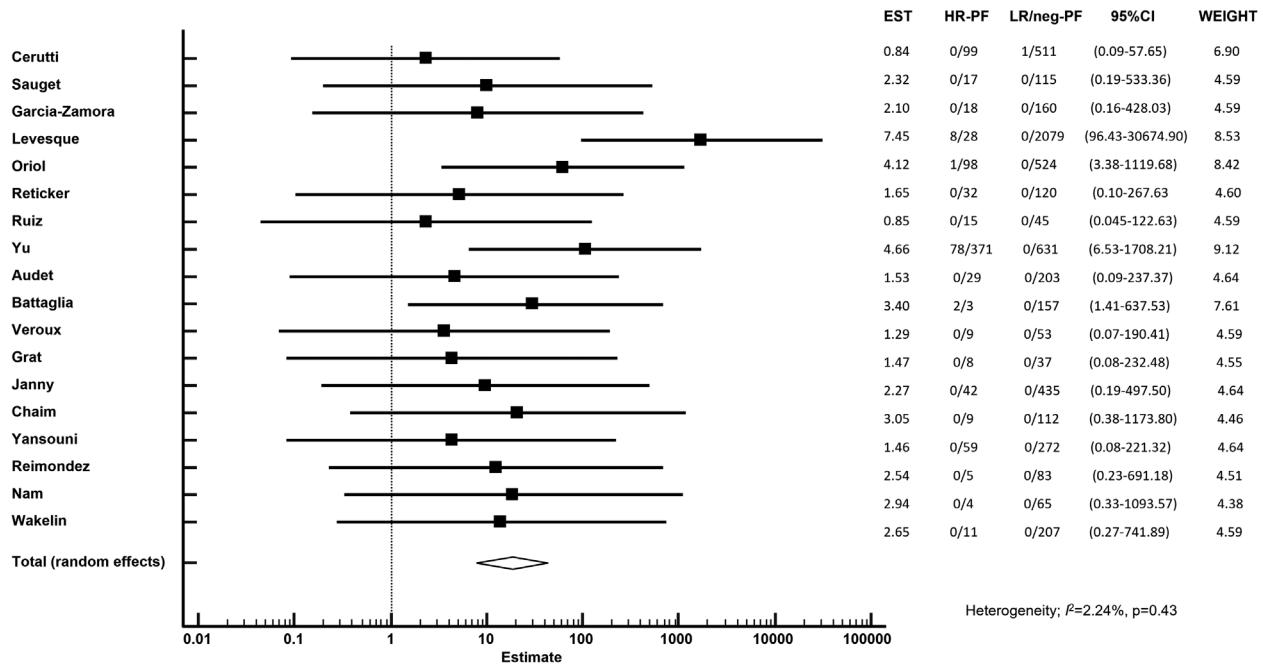

FIGURE 2 Forest plot of graft arteritis rate in solid organ transplant (SOT) recipients with overall high-risk pathogens compared to low-risk/negative preservation fluid (PF)

4 | DISCUSSION

Our meta-analysis seems to underscore the association between positive PF for high-risk pathogens including fungi, Gram-negative bacteria, and some Gram-positive bacteria (e.g., Enterococci and *S. aureus*) and the risk of developing graft site arteritis in patients undergoing kidney and LT. However, the reliability of such findings is limited by the paucity of data about graft arteritis diagnosis and the moderate to high bias of included studies, reflecting the need for well-designed studies in this specific setting.

Septic arteritis is a rare complication of solid organ transplantation already been described in the last decades.[28,29] The impact of such events in SOT recipients is dramatic, frequently leading to artery rupture resulting in graft loss or death. Nowadays it is clear that screening and culturing donors should be performed with great rigor to reduce the risk of donor-derived infections.[30] However, although some

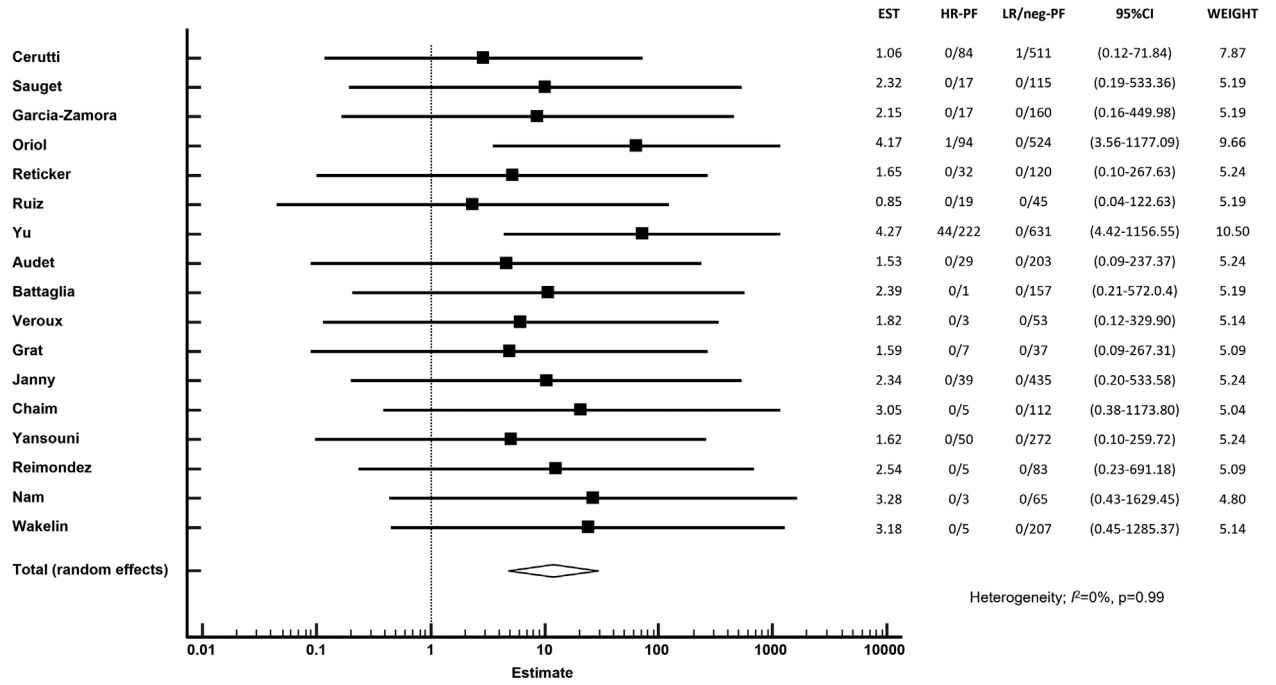

FIGURE 3 Forest plot of graft arteritis rate in solid organ transplant (SOT) recipients with bacterial high-risk pathogens compared to low-risk/negative preservation fluid (PF)

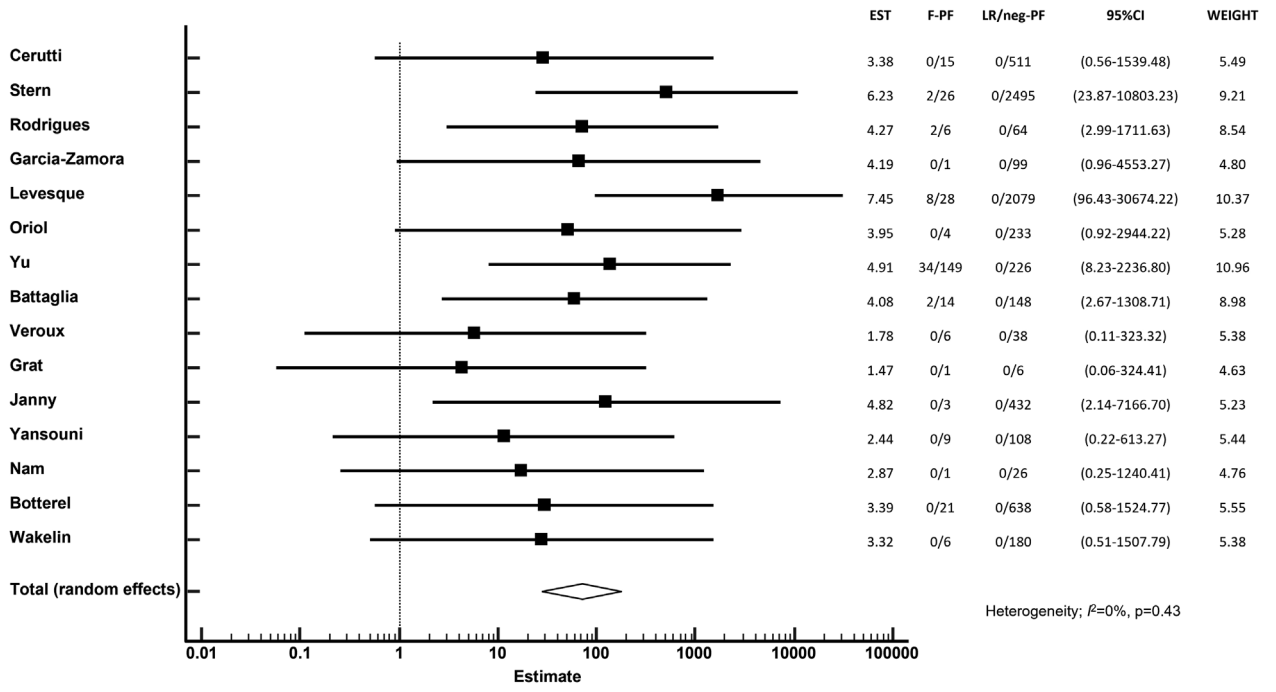

FIGURE 4 Forest plot of graft arteritis rate in solid organ transplant (SOT) recipients with fungal high-risk pathogens compared to low-risk/negative preservation fluid (PF)

procedures are mandatory, due to a well-known clinical impact on the recipient, such as recognizing bacteremic donors through blood cultures collection, the impact of culturing the PF is an argument still under debate.

A previous systematic review showed that the rate of positive PF cultures could be very high (62.5%), however, only a smaller rate of isolates could be considered as potentially clinically relevant[31]. Similarly, our data confirm that more than half of positive PFs were

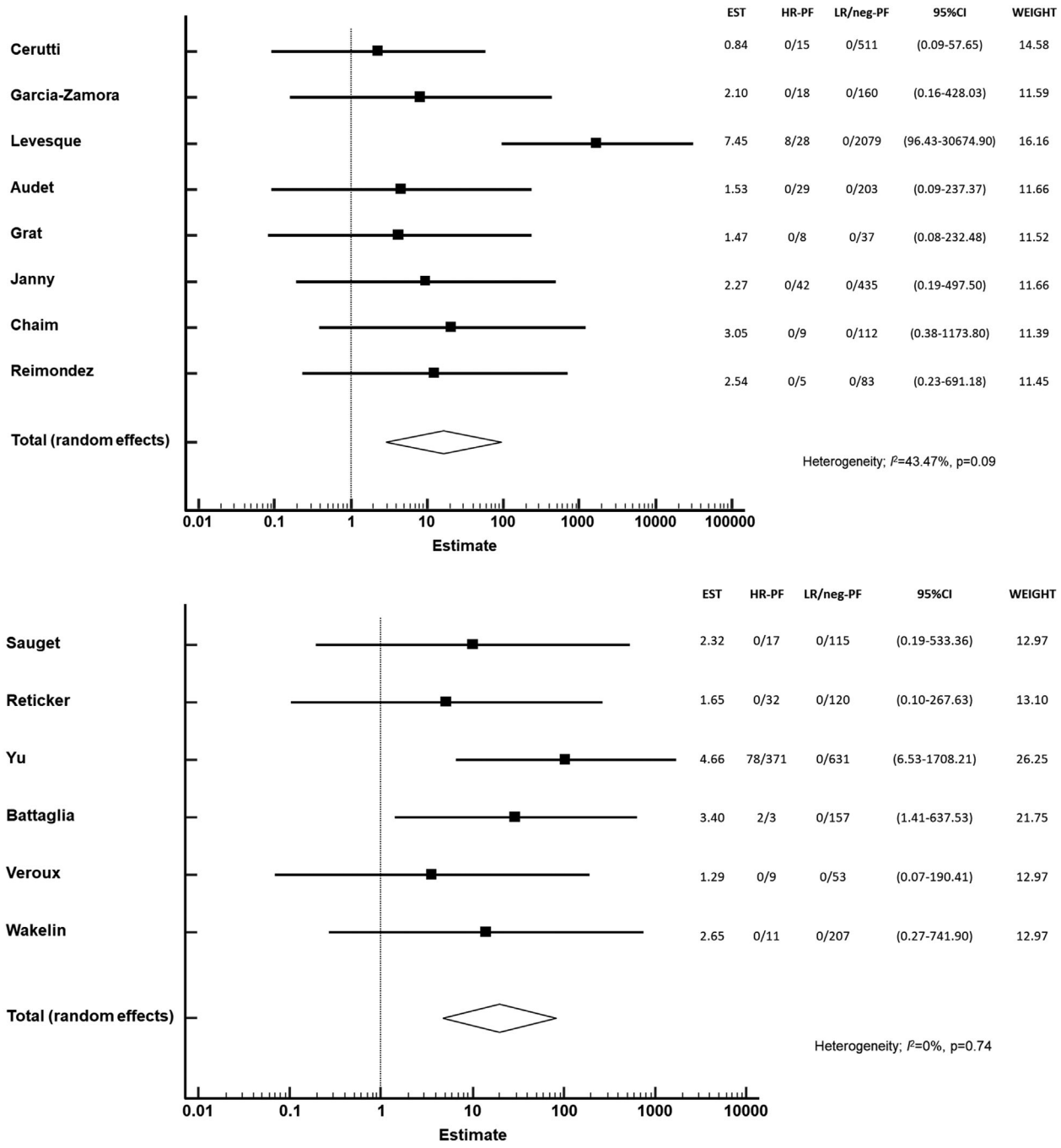

FIGURE 5 **Panel a** - Forest plot of graft arteritis rate among liver transplant recipients with a high-risk pathogen compared to low-risk/negative preservation fluid (PF). **Panel b** - Forest plot of graft arteritis rate among kidney transplant recipients with a high-risk pathogen compared to low-risk/negative PF

contaminated by a low-risk pathogen. Furthermore, our findings suggest that a PF yielding a low-risk pathogen is negligible, as the risk of graft arteritis development in this subgroup is similar to that of recipients with a negative PF.

The picture changes if we consider high-risk pathogens such as fungi. Several case reports focusing on mycotic aneurism development in recipients with a graft PF positive for *Candida* spp. have been described.[32,33] Indeed, although definitive and larger studies are lacking, international guidelines suggest a prophylactic approach with an azole if *Candida* spp. has been isolated from PF.[34]

Furthermore, we observed that also some bacteria, mostly Enterobacteria and Enterococci, seem to be strongly associated with an increased risk of developing arteritis. These bacteria may suggest a gastrointestinal breach as a potential source of graft contamination.[32] In the last years, the increase of donation after circulatory death in order to expand the donor pool could reflect an increased risk of possible

contaminations, considering the need of maintaining circulation during organ retrieval and pre-implantation machine perfusion of organs.[35,36]

In addition, it is worth underlying that the concordance between bacteria isolated from PF and those from the graft arteritis site was full. However, data about histological and microbiological diagnostic findings were missing from almost all reports. Thus, further studies with well-defined protocols for the early diagnosis of graft arteritis in all recipients and in particular in those with positive PF for high-risk pathogens are needed to confirm our results and to propose pre-emptive therapeutic approaches, such as repeated microbiological investigations (i.e., urine culture, blood culture, and serum Beta-D-Glucan detection), targeted antimicrobial treatment and close monitoring of vascular anastomosis, especially during the first month after transplant.

Limitations of our meta-analysis have to be addressed. Firstly, a high proportion of included studies showed a serious risk of bias. Secondly, the methodology for diagnosing graft arteritis as well as the time from transplantation to diagnosis was not specified in the majority of cases. Furthermore, data about other relevant donor samples, (i.e., blood cultures, urine, or respiratory cultures) and outcomes of patients diagnosed with graft arteritis were available only in a few studies, therefore a sub-analysis including such elements was not possible. Finally, antimicrobial prophylaxis regimens at transplantation and management of positive PF were not mentioned in the majority of included studies, and this could have played a role in the rate of graft arteritis development.

In conclusion, our data seem to support the practice of culturing PF of kidney and liver grafts and its potential role in increasing the risk of graft arteritis not only for fungi but also for some bacteria. However, they also underline the need for more robust studies assessing the impact of positive PF culture on the development of graft arteritis.

4.1 | Transparency declaration

The authors declare no conflict of interest related to the content of this manuscript.

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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 can be found online in the Supporting Information section at the end of this article.

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