Outcomes Following Use of Bovine Pericardium (Xenoprosthetic) Grafts for Reconstruction of Mycotic Aortic Aneurysms and Infected Aortic Grafts: A Systematic Review and Meta-Analysis

Samuel Grills,[1] Nadia El-Diaz,[1] Abigail Walker-Jacobs,[2] Joseph Borucki,[1,2] and Philip Stather,[1,2] Norwich, United Kingdom

Background: Infected aortic grafts and mycotic aneurysms represent one of the most complex challenges faced by vascular surgeons. Treatment has progressed from extra-anatomical bypass to in situ reconstruction. Additionally, bovine pericardium reconstruction (BPR) has increased, due to accessibility and reduced lower limb morbidity. There remains, however, limited evidence for its use. The aim is to pool all known data to understand outcomes following BPR of mycotic aneurysms or infected vascular grafts.

Methods: A systematic review was conducted in November 2021 with subsequent computerized meta-analysis of the pooled results and a final search in March 2022. Three databases, Excerpta Medica dataBASE (EMBASE), Cumulative Index of Nursing and Allied Health Literature (CINAHL), and National Institutes of Health PubMed (PubMed), were searched for the search term "(bovine OR xenoprosthetic) AND (aneurysm)", according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Results: From 9 studies, there were 133 patients: 67% graft infections and 33% mycotic aneurysms. Fifty-seven percent of reconstructions were in the abdominal aorta and 33% were in the thoracic aorta. One hundred fifty-eight pathogens were identified, including *Staphylococcus aureus* (23%), *Candida albicans* (13%), and *Escherichia coli* (13%). In 12%, no microorganisms were identified.

Thirty-day mortality was 19.14% (CI 10.83−28.71), late mortality was 19.08% (confidence interval [CI] 7.76−32.83), and overall mortality was 40.20% (CI 29.82−50.97). One patient died intraoperatively. There were a total of 151 in-hospital complications after 30 days postoperation. Common complications were acute renal failure (17%), pneumonia (14%), delirium (12%), respiratory insufficiency (11%) and renal insufficiency (7%). Lower limb ischemia was low, occurring in 5.66% (CI 0.54−13.82) of patients. Loss of graft patency leading to reintervention occurred in 1.20% (CI 0.00−7.71) of the grafts. Reinfection rate was 0.00% (CI 0.00−1.21).

Declaration of conflict of interest: There are no conflicts of interest.

[1]Norwich Medical School, University of East Anglia, Norwich, UK.

[2]The Norfolk & Norwich University Hospital Vascular Unit, Norfolk and Norwich University Hospital, Norwich, UK.

Correspondence to: Samuel Grills, Norwich Medical School, University of East Anglia, 17 Admirals Walk, Greenhithe, Kent, UK DA9 9QP; E-mail: samuelgrills@yahoo.co.uk

Ann Vasc Surg 2024; 102: 181–191
https://doi.org/10.1016/j.avsg.2023.11.037
© 2024 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
Manuscript received: May 4, 2023; manuscript accepted: November 8, 2023; published online: 1 February 2024

Conclusions: This meta-analysis highlights low reinfection and high graft patency using BPR with medium-length follow-up; however, there remain limited long-term and comparative data regarding options for aortic reconstruction. As expected in this complex cohort, the complication rate and 30-day mortality remain high.

INTRODUCTION

Infected abdominal aortic aneurysm prosthetic grafts and mycotic (native infection) abdominal aortic aneurysms represent one of the most complex challenges faced by vascular surgeons.[1,2] Mycotic aneurysms and prosthetic graft infections of the aorta are rare, but can spontaneously rupture; this is associated with a high mortality of 63−100%.[3−5] Despite being different clinical entities, prosthetic graft infection and mycotic aneurysms have similar prognoses and approaches for management; the main difference being that prosthetic graft infections require debridement of the infected graft, rather than infected tissue. Even when treated, both types of infected abdominal aortic aneurysms have a high mortality and a very high morbidity.[6] Recently, gold standard treatment of these infected abdominal aortic aneurysms has moved from extra-anatomical bypass to in situ reconstruction. This follows research suggesting that in situ reconstruction has lower mortality rates, higher graft patency and lower amputation rates.[7,8] O'Connor et al. also identified lower reinfection rates when using in situ reconstruction, though this was dependent on the type of material used.[7]

In situ reconstruction involves endovascular debridement of the infected material, followed by a reconstruction of the vessel.[9] For this procedure, there is the choice of using a synthetic graft (such as silver-coated graft or rifampicin-soaked graft), a cryopreserved allograft, an autogenous vein or a xenoprosthetic graft, with debate among literature about which is most effective.[7,10] Bovine pericardium can be used as a xenoprosthetic graft and its use for in situ reconstruction has increased recently. Bovine pericardium is fairly resistant to infection and can be stored for easy availability in emergency situations and are easily accessible.[11,12] These grafts are also relatively inexpensive and can be adjusted to fit the size or shape needed for the reconstruction, including bifurcations.[13,14] However, there remains a lack of evidence for its use, with no previous systematic reviews. This means that current data about its effectiveness, such as mortality rates and reinfection rates are based off results from small, individual studies.

The aim of this study was to identify current research on the use of bovine pericardium grafts and to undertake a meta-analysis of outcomes to assess the suitability of this graft material for in situ reconstruction of infected aneurysms and infected prosthetic grafts.

What this Paper Adds

Existing literature has shown that bovine pericardium can be used as a graft material for in situ reconstruction of infected vascular grafts and mycotic aneurysms. Until now, there has not been enough published literature for a complete systematic review on this application of bovine pericardium grafts. This systematic review and meta-analysis collates existing data to analyze the suitability of bovine pericardium grafts for in situ reconstruction of infected aortic grafts and mycotic aneurysms.

METHODS

Search Strategy

The Healthcare Databases Advanced Searches system was used in November 2021 to search 3 databases, Excerpta Medica dataBASE (EMBASE), Cumulative Index of Nursing and Allied Health Literature (CINAHL), and National Institutes of Health PubMed (PubMed), since the date of inception for the search term ''(bovine OR xenoprosthetic) AND (aneurysm)''. The literature search was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[15] Two independent assessors, SG and NE, reviewed results to identify eligible studies. Duplicates were removed, the results were exported into Microsoft Excel, and the papers were then reviewed and assessed for eligibility, firstly by title and subsequently by abstract. A third independent assessor, PS, settled any disagreements between the reviewers and reviewed the final literature selection. A final search was conducted in March 2022.

Eligibility Criteria

Studies were eligible if the following criteria were satisfied.

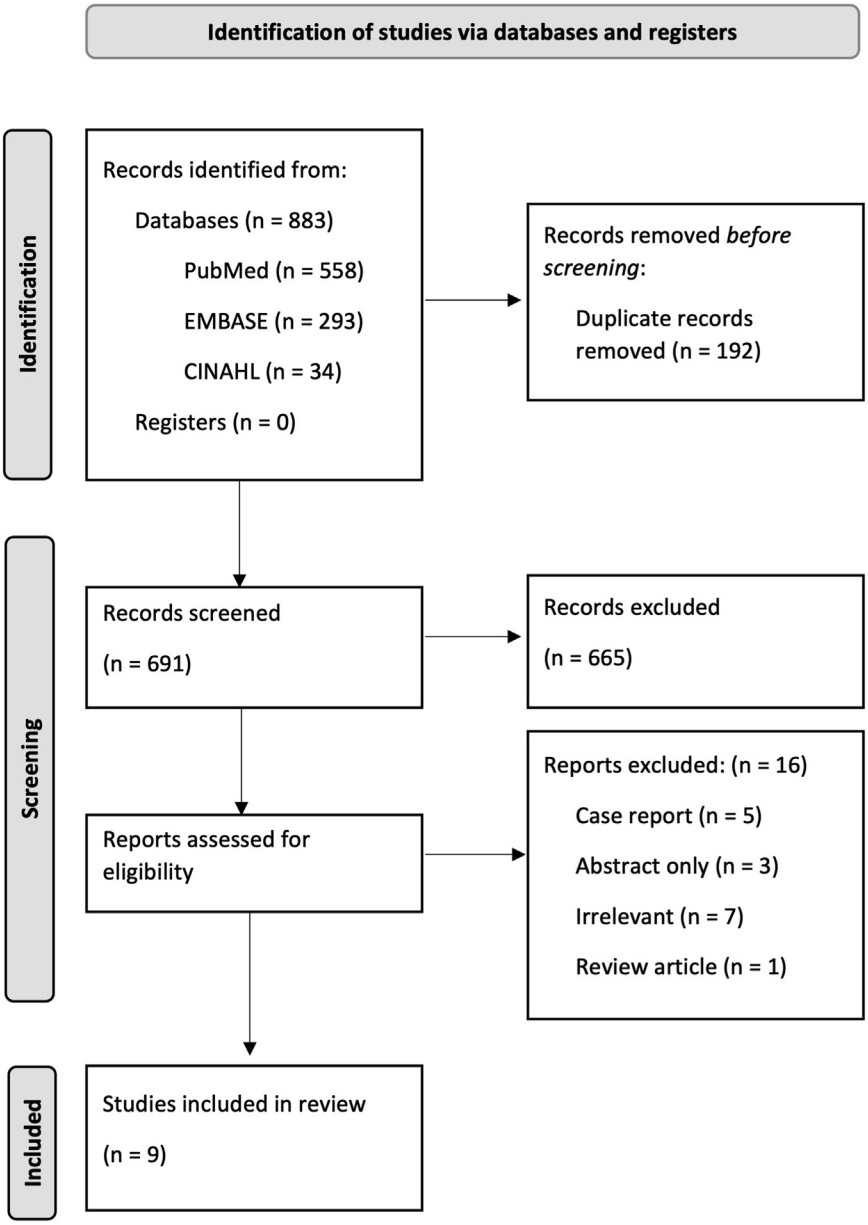

Fig. 1. PRISMA flow diagram for the identification of studies via databases and registers.

- The study type was a randomized control trial, cohort study, or case series.
- Studies must have a minimum of 2 patients. Single-patient case reports were not included.
- Full literature papers had been published. Abstract-only papers and conference proceedings were not included.
- Participants underwent in situ reconstruction of the aorta.
- Bovine pericardium grafts were used.
- Participants were being operated on for native vascular infection or infected prosthetic graft.

Data Extraction

Full articles from the eligible studies were retrieved and the details of each paper were collected. Data were extracted from the final selection of eligible papers by 2 independent reviewers, SG and AWJ. There were no papers for which the authors had to be contacted about information. Numerical data were collected from tables within the papers or appendices. Extracted data were combined in a Microsoft Excel spreadsheet and then presented as either a raw number or a percentage. The quality of the studies and risk of bias was assessed using

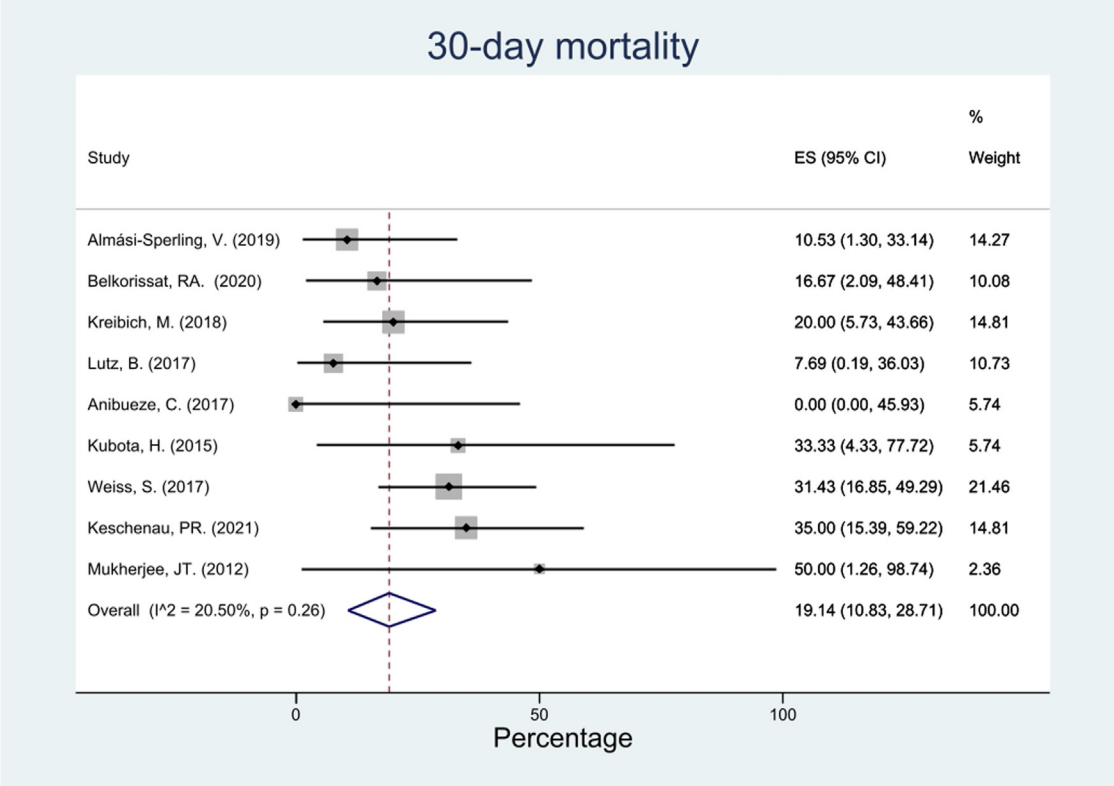

Fig. 2. The 30-day mortality for each study as a percentage.

the Joanna Briggs critical appraisal tool by SG and NE (Supplementary Table S1).[16] Any disagreements were discussed and resolved by a third party, PW.

Outcomes

Primary outcomes identified were as follows.

1. Mortality: 30-day mortality, late mortality, and total mortality.
2. The rate of aortic reinfection.
3. Graft patency.
4. Lower limb ischemia.

Thirty-day mortality was chosen to represent short-term mortality—these data were available from all studies. This includes patients who died intraoperatively. Late mortality includes any death during the whole length of follow-up after 30 days.

Secondary outcomes included the following: type and frequency of causative bacteria identified, follow-up length, and complications. Where individualized follow-up length data were not available, the mean was used to calculate the overall follow-up length.

For each study, data were also collected about the study participants, including demographics, operation type, indication for operation and location of repair. Risk of bias was also assessed for all of the studies. Computerized statistical analysis using StataMP 17 was conducted for each of the primary outcomes to pool the data and determine the meta-analysis.

RESULTS

Background Patient Information

Literature search identified 883 studies; in total, 9 were eligible for inclusion (Fig. 1). All 9 of the studies were published after 2012. Overall, 133 patients underwent aortic reconstruction with bovine pericardial grafts: 68% were for prosthetic graft infections; 32% for native infection. Of these patients, 104 were males and 29 were female (m:f ratio of 3.6:1) and mean age was 67.8 (range of 28—84 years). Kubota et al. did not report preexisting patient comorbidities.[17] In the remaining 127 patients, preexisting comorbidities included hypertension (87%), coronary heart disease (38%), peripheral artery disease (28%), diabetes mellitus

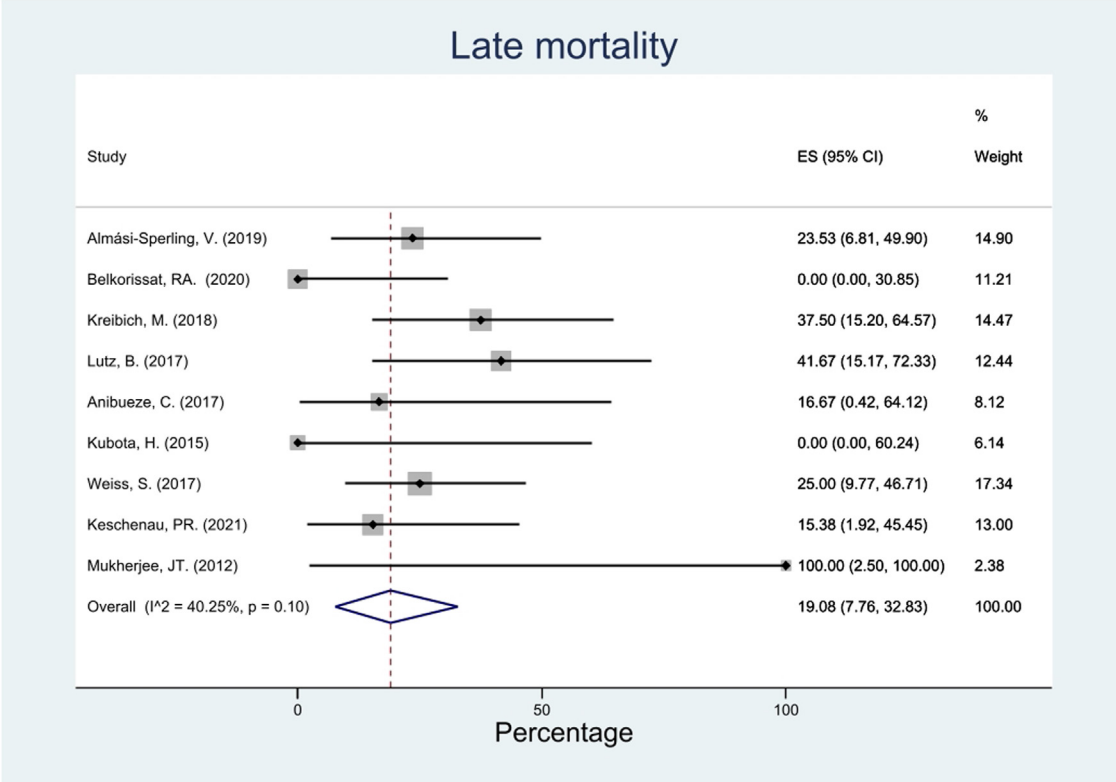

Fig. 3. The late mortality for each study as a percentage.

(26%), chronic renal failure (23%), chronic obstructive pulmonary disease (21%), and malignant cancer (5%).

Details of Procedure

Seventy-six (57%) in situ reconstructions were performed in the abdominal aorta and 44 (33%) in situ reconstructions were performed in the thoracic aorta. Lutz et al. did not distinguish between locations within the aorta.[11] Indications for the operations were prosthetic graft infection (67%) and mycotic aneurysm (33%). The length of stay after the procedure ranged from 4 days to 177 days. Length of stay was not reported by 4 studies.

Follow-up

The mean follow-up from 6 studies was 25 months (1−65 months). Three papers did not report mean follow-up data; these reported median follow-up data ranging from 6 to 14 months. Follow-up included clinical assessment and in most studies blood tests were done for white blood cell count and C-reactive protein. Computed tomography (CT) scans were done between 3 and 12 months postsurgery in 8/9 studies to determine graft patency and look for signs of reinfection, such as fluid collections or air bubbles. Almási-Sperling et al. reported the use of ultrasound during follow-up instead of CT for imaging the graft postoperatively.[14]

Mortality

The mortality rates varied across the studies, particularly late mortality (the total mortality during follow-up). Thirty-day mortality ranged from 0% (0/6) in Anibueze et al. to 35% (7/20) in Keschenau et al.[13,18] Both Belkorissat et al. and Kubota et al. reported late mortality rates of 0%, compared to 42% reported by Lutz et al.[11,17,19] Mukherjee et al. reported an early mortality rate of 50% and a late mortality of 100%; however, this was in a sample of 2 patients and the researchers continued follow-up for the second patient until death.[20] Overall, 30-day mortality was 19.14% (confidence interval [CI] 10.83−28.71) (Fig. 2) with low heterogeneity between studies (I^2 of 20.50%). Overall late mortality was 19.08% (CI 7.76−32.83) (Fig. 3) with moderate heterogeneity between studies (I^2 of 40.25%). Across studies, only 1 patient died intraoperatively

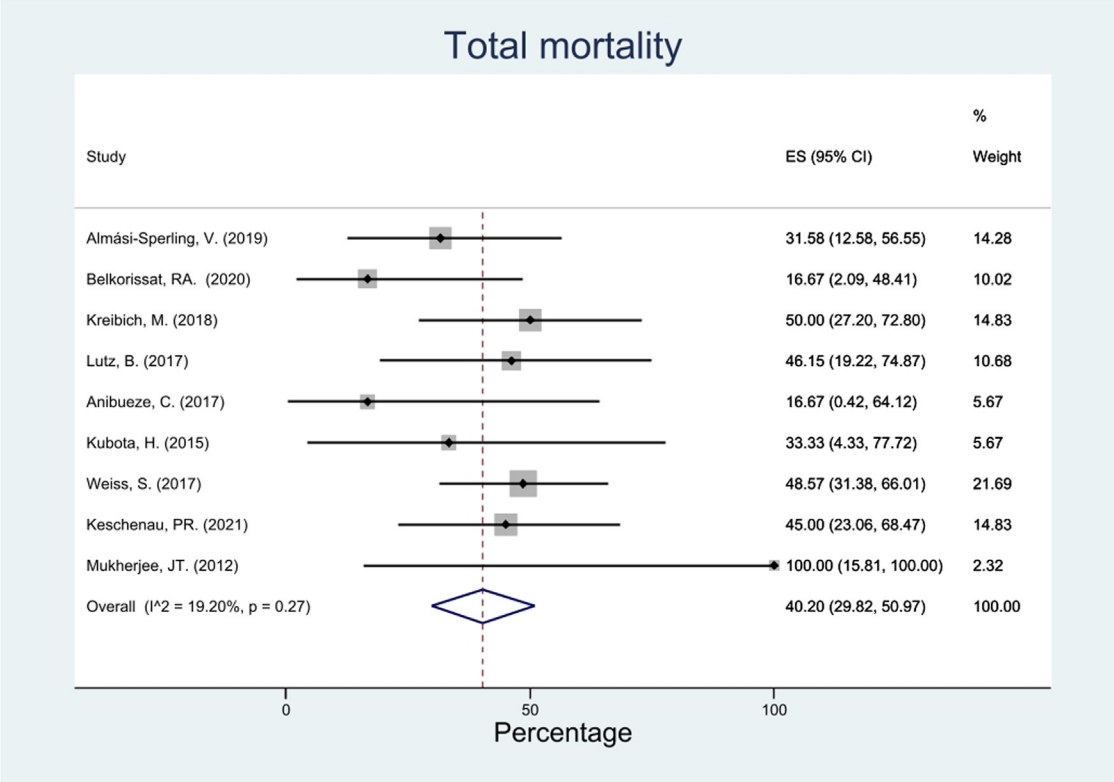

Fig. 4. The total mortality for each study as a percentage.

(0.75% intraoperative mortality) from acute cardiac insufficiency and Keschenau et al. states that the patient ''suffered from congestive heart failure'' and had ''requested the operation despite the high operative risk''.[18] The total mortality across all studies was 40.20% (CI 29.82–50.97) (Fig. 4).

Reinfection

Of the 9 studies, 8 studies reported complete freedom from reinfection during follow-up. Only Lutz et al. reported reinfection following aortic reconstruction in 2 patients (15%).[11] Meta-analysis of the data calculated the overall reinfection rate at 0.00% (CI 0.00–1.21) (Fig. 5).

Loss of Graft Patency

Six out of 9 studies reported graft patency rates of 100% during follow-up. Mukherjee et al., Almási-Sperling et al. and Kreibich et al. reported loss of graft patency in 1, 2, and 4 patients respectively.[14,20,21] Overall, loss of graft patency leading to reintervention occurred in 1.20% (CI 0.00–7.71) of the grafts (Fig. 6).

Complications

Lower limb ischemia was low, occurring in 5.66% (CI 0.54–13.82) of patients (Fig. 7). Of these 9 patients, 3 required lower limb amputation. Pseudoaneurysms of the graft reconstruction occurred in 3 patients. There were 151 complications (major and minor) in patients who survived past 30 days post-operation (Supplementary Table S2). Weiss et al., reported the highest complication rate, presenting 84 complications in 35 patients.[22] The most common complications were acute renal failure (17%), pneumonia (14%), delirium (12%), respiratory insufficiency (11%) and functional renal insufficiency (7%). Six papers reported the number of patients without any complications totaling 27 (out of 73). Weiss et al., Lutz et al. and Belkorissat et al., did not report the number of patients who were complication-free.[11,19,22]

Causative Pathogens

All studies included results of preoperative cultures and 158 causative pathogens were identified from over 32 bacterial and fungal species (Supplementary Table S3). The 3 most prevalent

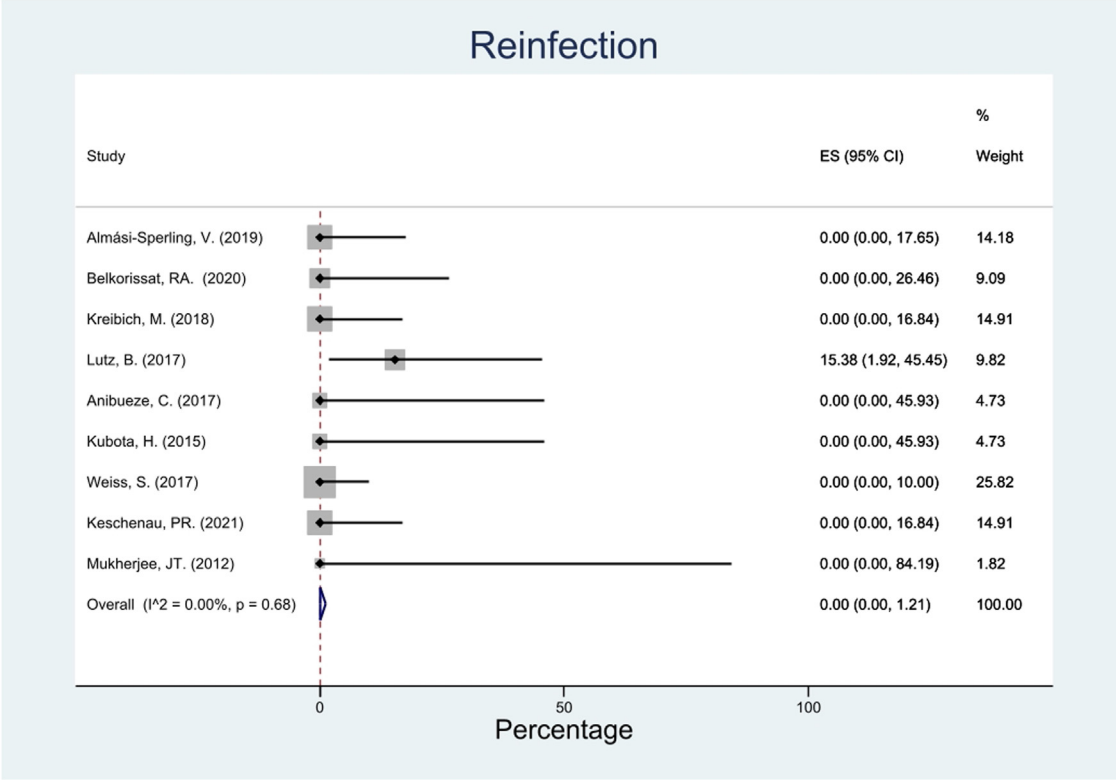

Fig. 5. The reinfection rates for each study as a percentage.

pathogenic causes were *Staphylococcus aureus* (23%), *Candida albicans* (13%) and *Escherichia coli* (13%). In 16 patients (12%), no microorganisms were identified. With 158 pathogens identified in 117 patients, there is evidence that some patients had multiple causative organisms but it is not clear how many cases were multimicrobial.

DISCUSSION

Following the increase in the use of in situ reconstruction over extra-anatomic bypass for infected aortae, there has been ongoing debate about which graft material is the most effective. When considering the optimal graft material for in situ reconstruction of infected abdominal aortic aneurysms, it is important to consider the suitability of the material and its benefits over other available options. An ideal graft would remain patent, remain free from reinfection, be associated with low mortality, and have few adverse complications. This meta-analysis has identified very low reinfection rates when using bovine pericardium for in situ reconstruction with low rates of graft occlusion, low rates of lower limb ischemia and rates of mortality and complications, which are high, as expected. Benefits of using bovine pericardium include ease of access, relative inexpensiveness and applicability in emergency settings. Given these results, bovine pericardium appears to be a suitable material with some advantages over other products available.

Early mortality with in situ reconstruction ranges between 0 and 48% with existing literature showing that autogenous veins generally have the lowest early mortality rates (0−17%) and cryopreserved allografts generally reporting highest early mortality rates (2−48%).[9] The early mortality of 19.14% (CI 10.83−28.71) in this study is acceptably high and is comparable to available data on other graft materials for in situ reconstruction. Multiorgan failure after sepsis was the attributed cause of early mortality in at least 10 patients. Sepsis can be difficult to avoid in patients undergoing in situ reconstruction for graft infection due to the delayed presentation, the extensive spread of causative infection and the urgency of repair.[18] Although the graft infection is cleared, persistent systemic infection leading to sepsis represents a challenge to prevent mortality. Other causes of early mortality included infective

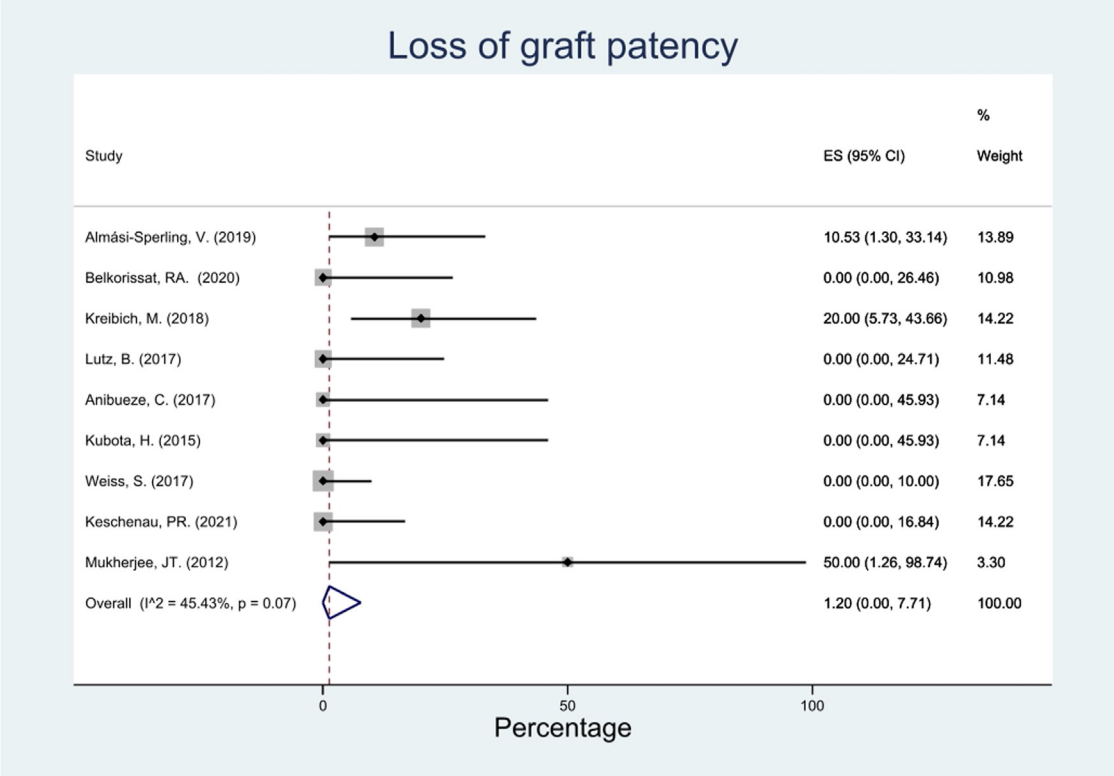

Fig. 6. The loss of graft patency for each study as a percentage.

endocarditis, respiratory failure, hemorrhagic shock and cardiac arrest. The total mortality rate of 40% is significantly better than mortality rates of untreated patients (up to 100%) and high mortality rates are generally expected, given the complexity of managing infected aortic grafts and mycotic aneurysms.[9] Given the high risk nature of aortic reconstructions and the significant patient comorbidities associated with this presentation, it is unlikely that the choice of graft would be able to significantly reduce this mortality rate. At least 11 patients (out of a total 55) of these patients who died were directly stated to have died of non−aortic-related death and represent the significance of comorbidities in patients susceptible to infected aortae. For example, 1 patient who died of preexisting malignant cancer.

This meta-analysis showed that bovine pericardium is very effective at preventing reinfection, with a 0% (CI 0.00−1.21) reinfection rate. This is lower than the reinfection rates of published literature for autologous vein (5%), cryopreserved allografts (9%), rifampicin-covered prosthetic grafts (11%) and silver-coated prosthetic grafts (11%).[5,23] However, Lutz et al. has shown that freedom from reinfection is not always possible with bovine pericardium and highlights the need to completely clear the initial infection, to avoid reinfection and subsequent graft rupture.[11] Also, freedom from reinfection is not specific to bovine pericardium and has been reported with other graft materials, including autogenous vein and cryopreserved allografts as seen by Dorweiler et al. and Heo et al.[24,25] However, these were single-case series of 86 and 25 patients respectively, and are not consistent with subsequent systematic reviews or meta-analyses. Actual reinfection rates are unlikely to be 0% in any study about in situ reconstruction, as it is hard to definitively exclude reinfection. Further to this, most studies only did follow-up imaging 3−12 months postoperatively, relying on clinical and biochemical signs to assess for systemic signs of acute reinfection, which may have missed a minor, persistent reinfection. However, it is reassuring that the rate of significant reinfection requiring repeat operation is 0% and the possibility of minor, subclinical reinfection is less clinically important and can be investigated in future research.

The low graft occlusion rate of 1.20% (CI 0.00−7.71) highlights the low graft thrombosis risk when using xenoprosthetic material for grafts. When compared to the graft occlusion rates reported by Batt et al., bovine pericardial grafts were similar

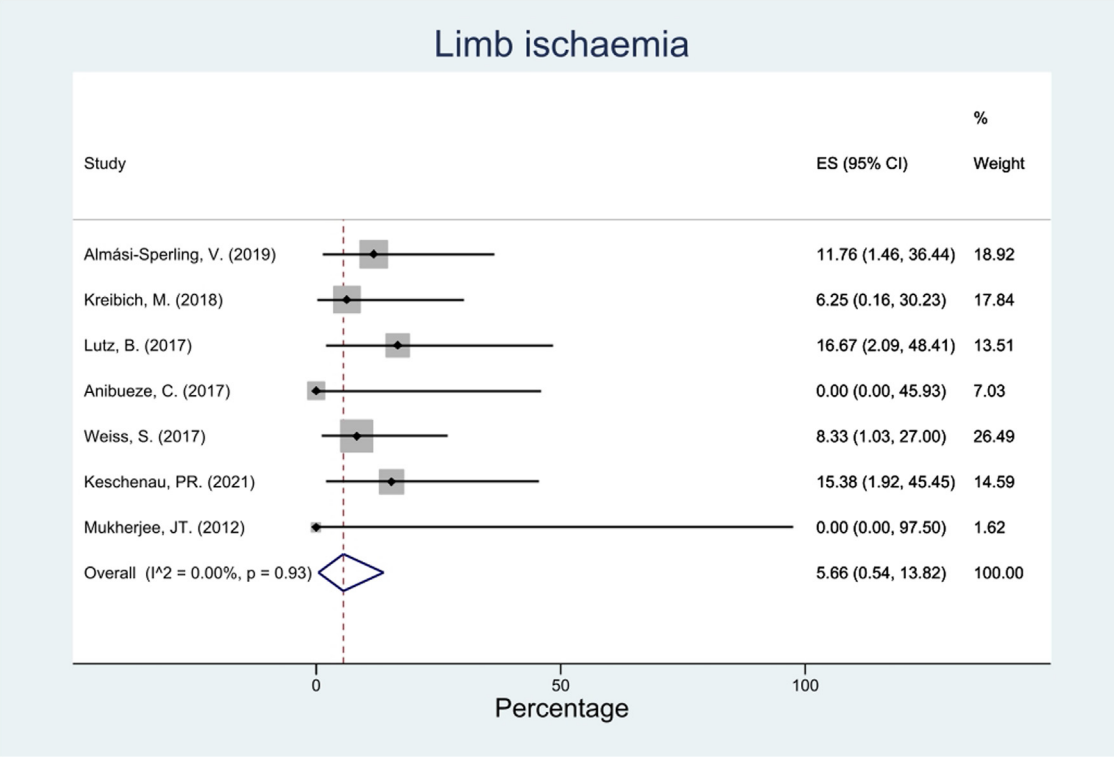

Fig. 7. Frequency of limb ischaemia for each study as a percentage.

to autogenous veins (2%) and lower than silver-coated prosthetic grafts (7%), cryopreserved allografts (13%), rifampicin-coated prosthetic grafts (11%), and standard prosthetic grafts (10%).[5] Three studies in this paper, Almási-Sperling et al., Kreibich et al., and Mukherjee et al., presented loss of graft patency with bovine pericardium.[14,20,21] In Mukherjee et al., this was bovine patch dehiscence which led to mortality, whereas in Almási-Sperling et al. and Kreibich et al. loss of graft patency was due to thrombotic occlusion and was successfully treated with bypass. Kubota et al. identified postoperative treatment with anticoagulant or antiplatelet treatment as ''a matter of controversy'' and is a potential area of future research.[17] As well as this, comparison in the use of tube against bifurcated grafts should be explored, although the distribution of these was unknown within these studies.

Pseudoaneurysms of the suture line had been identified as bovine graft-specific risks by Lutz et al., potentially leading to mortality.[11] This was supported by Kreibich et al. who reported 2 cases of suture line aneurysms: 1 leading to early mortality and 1 being successfully treated during follow-up.[21] Pseudoaneurysms were also seen in Kubota et al., although neither of the 2 patients with pseudoaneurysms had evidence of concurrent infection and both survived.[17] However, pseudoaneurysms were not raised as concerns by the other studies included in this systematic review. The total number of pseudoaneurysms during follow-up was only 4, suggesting that it is an uncommon complication in patients surviving past the early mortality. The use of autogenous vein grafts has a recognized link to increased risk of lower limb ischemia and amputation, with published amputation rates up to 18%.[9,23,26] In comparison, only 5.66% (CI 0.54–13.82) of patients in this study experienced lower limb ischemia and amputation was seen in just 3 patients. As such, lower limb ischemia can be regarded as an uncommon complication of bovine pericardium grafts and provides an advantage over autogenous vein grafts. This is akin to available data from similar studies on cryopreserved allografts, rifampicin-coated prosthetic grafts and silver-coated prosthetics. However, the studies reporting high amputation rates with autogenous vein grafts also report lower mortality and it could be possible that the lower amputation rates occur when patients are not surviving long enough for critical limb ischemia to occur.

The total number of complications is high, as expected due to the large physical strain of these major operations and the complication rate is similarly high with other graft materials. Noel et al. reported that 51% of patients treated with aortic allografts experienced at least 1 complication and Langenskiöld et al. reported that 52% of patients treated with autologous vein experienced at least 1 complication; however, both materials demonstrated lower total numbers of complications per patient than bovine pericardium.[12,27] A majority of the complications from this study were acute, highlighting a need for close postoperative monitoring following in situ reconstruction of infected aortae. However, the common complications seen here are not specific to in situ reconstruction or bovine pericardium. The most frequently observed complication, acute renal failure, is a common complication of vascular surgery, occurring in up to 30% of patients undergoing vascular surgery.[28] Similarly, pneumonia, delirium and respiratory insufficiency are common complications of surgical procedures.[29]

For a complete assessment of the suitability of bovine pericardium, the outcomes should be compared with other graft materials. Rifampicin-soaked grafts have low early mortality rates (6–32%).[5,9] However, as a synthetic material, it is prone to reinfection (11%) and the use of rifampicin-bonded polyester can lead to development of rifampicin-resistance. Silver-coated grafts have no associated resistance but have similarly high reinfection rates.[30] Although cryopreserved allografts are more resistant to reinfection (0–14%), they are associated with high graft occlusion rates and high early mortality rates (up to 48%).[31] Autogenous vein grafts have low reinfection (6%) and low early mortality rates (up to 17%).[32] Despite this, autogenous vein grafts are not always suitable because the vein harvesting is time consuming, cannot be done in emergency situations and leads to high lower limb morbidity (amputation rates up to 17%).[32]

Bovine pericardium is highly resistant to infection and has a low graft occlusion rate. Mortality rate is moderately low but there is a high complication rate. Bovine pericardium is easily accessible and relatively inexpensive when compared to other graft materials.[21] The use of patches to create the grafts allows for construction of all necessary diameters and the grafts can be tailored to the individual patients. This reduces the risk of graft stenosis and means that bovine pericardium can be adapted for use in all aortic segments. Another advantage of bovine pericardium grafts is that it can be stored and used in an emergency setting. This is particularly beneficial in the setting of infected aortae due to the delayed presentation and the urgency of surgical management. As well as this, no additional tissue incision is necessary to complete the reconstruction, unlike autogenous femoral vein grafts.

LIMITATIONS

Conditions external to the graft material are likely to have impacted the patient outcomes in this study. Factors such as the use of postoperative antibiotics and in-hospital care could not be analyzed due to inconsistency in reporting between the studies included in this paper. Further to this, patient reinfection may have been under-reported, as it is impossible to rule out infection in some of the patients, especially those who died within 30 days or did not have imaging after 3–12 months.

Another limitation is that there are currently still only a small number of studies published on the use of bovine pericardium for infected aortae and all of the studies included here are retrospective studies with small sample sizes and short follow-up lengths. This limitation also means that for this systematic review, prosthetic graft infection and mycotic aneurysms have been classed together, despite being different clinical entities, to maximize the amount of data which could be included.

CONCLUSION

This meta-analysis highlights that bovine pericardium grafts represent a suitable option for in situ reconstruction of infected grafts and mycotic aneurysms of the abdominal aorta. Within this small cohort of patients with short-term to medium-length follow-up, this material shows low reinfection rates and high graft patency rates, with mortality rates akin to those published with other graft materials. The graft material is unlikely to be able to further decrease mortality rates from in situ reconstruction and the impact of different surgical techniques, preexisting comorbidities and postoperative care should be investigated in future research. The advantages of using bovine pericardium grafts include low rates of lower limb ischemia, ease of access, and availability for emergency situations. However, there remains a lack of long-term data and the data which are available are limited by low cohort sizes. Further studies with large sample sizes and long follow-up are needed to allow true comparison of bovine pericardium grafts with other graft materials and determine how to reduce

mortality. On top of this, more research into the effectiveness of bovine grafts will allow comparison of outcomes by anatomical site of infection. Future studies should include continued use of CT imaging in the long-term, alongside clinical and biochemical assessment to verify the very low reinfection rate.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.avsg.2023.11.037.

REFERENCES

1. Oderich GS, Panneton JM, Bower TC, et al. Infected aortic aneurysms: aggressive presentation, complicated early outcome, but durable results. J Vasc Surg 2001;34:900–8.
2. Bunt T. Vascular graft infections: an update. Cardiovasc Surg 2001;9:225–33.
3. Mitrev ZK, Anguseva TN. Life-threatening surgery for mycotic aneurysm. Aorta (Stamford) 2013;1:193–7.
4. Shiraev T, Barrett S, Heywood S, et al. Incidence, management, and outcomes of aortic graft infection. Ann Vasc Surg 2019;59:73–83.
5. Batt M, Feugier P, Camou F, et al. A meta-analysis of outcomes after in situ reconstructions for aortic graft infection. Angiology 2018;69:370–9.
6. Sörelius K, Budtz-Lilly J, Mani K, et al. Systematic review of the management of mycotic aortic aneurysms. Eur J Vasc Endovasc Surg 2019;58:426–35.
7. O'Connor S, Andrew P, Batt M, et al. A systematic review and meta-analysis of treatments for aortic graft infection. J Vasc Surg 2006;44:38–45.e8.
8. Heinola I, Kantonen I, Jaroma M, et al. Editor's choice – treatment of aortic prosthesis infections by graft removal and in situ replacement with autologous femoral veins and fascial strengthening. Eur J Vasc Endovasc Surg 2016;51:232–9.
9. Chakfé N, Diener H, Lejay A, et al. Editor's choice – European society for vascular surgery (ESVS) 2020 clinical practice guidelines on the management of vascular graft and endograft infections. Eur J Vasc Endovasc Surg 2020;59:339–84.
10. Töpel I, Uhl C, Ayx I, et al. Xenografts in septic vascular surgery. Gefässchirurgie 2016;21:55–8.
11. Lutz B, Reeps C, Biro G, et al. Bovine pericardium as new technical option for in situ reconstruction of aortic graft infection. Ann Vasc Surg 2017;41:118–26.
12. Langenskiöld M, Persson SE, Daryapeyma A, et al. Deep femoral vein reconstruction for abdominal aortic graft infections is associated with low aneurysm related mortality and a high rate of permanent Discontinuation of antimicrobial treatment. Eur J Vasc Endovasc Surg 2021;62:927–34.
13. Anibueze C, Sankaran V, Sadat U, et al. Neoaortic xenoprosthetic grafts for treatment of mycotic aneurysms and infected aortic grafts. Ann Vasc Surg 2017;44:419.e1–419.e12.
14. Almási-Sperling V, Heger D, Meyer A, et al. Treatment of aortic and peripheral prosthetic graft infections with bovine pericardium. J Vasc Surg 2020;71:592–8.
15. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71.
16. Joanna Briggs Institute. Critical appraisal tools [Internet]. Available at: https://jbi.global/critical-appraisal-tools. Accessed June 5, 2022.
17. Kubota H, Endo H, Noma M, et al. Xenopericardial roll graft replacement for infectious pseudoaneurysms and graft infections of the aorta. J Cardiothorac Surg 2015;10:133.
18. Keschenau PR, Gombert A, Barbati ME, et al. Xenogeneic materials for the surgical treatment of aortic infections. J Thorac Dis 2021;13:3021–32.
19. Belkorissat RA, Sadoul C, Bouziane Z, et al. Tubular reconstruction with bovine pericardium Xenografts to treat native aortic infections. Ann Vasc Surg 2020;64:27–32.
20. Mukherjee JT, Nautiyal A, Labib SB. Mycotic aneurysms of the ascending aorta in the absence of endocarditis. Tex Heart Inst J 2012;39:692–5.
21. Kreibich M, Siepe M, Morlock J, et al. Surgical treatment of native and prosthetic aortic infection with Xenopericardial tube grafts. Ann Thorac Surg 2018;106:498–504.
22. Weiss S, Tobler EL, von Tengg-Kobligk H, et al. Self made Xeno-pericardial aortic tubes to treat native and aortic graft infections. Eur J Vasc Endovasc Surg 2017;54:646–52.
23. Pallister ZS, Chung J. Femoral vein reconstruction for aortic infections. Vasc Spec Int 2021;37:4–13.
24. Dorweiler B, Neufang A, Chaban R, et al. Use and durability of femoral vein for autologous reconstruction with infection of the aortoiliofemoral axis. J Vasc Surg 2014;59:675–83.
25. Heo SH, Kim YW, Woo SY, et al. Recent results of in situ abdominal aortic reconstruction with cryopreserved arterial allograft. Eur J Vasc Endovasc Surg 2017;53:158–67.
26. Aavik A, Lieberg J, Kals J, et al. Ten years experience of treating aorto-femoral bypass graft infection with venous allografts. Eur J Vasc Endovasc Surg 2008;36:432–7.
27. Noel AA, Gloviczki P, Cherry KJ, et al. Abdominal aortic reconstruction in infected fields: early results of the United States cryopreserved aortic allograft registry. J Vasc Surg 2002;35:847–52.
28. Kashani K, Steuernagle JH, Akhoundi A, et al. Vascular surgery kidney injury predictive score: a historical cohort study. J Cardiothorac Vasc Anesth 2015;29:1588–95.
29. Bennett KM, Kent KC, Schumacher J, et al. Targeting the most important complications in vascular surgery. J Vasc Surg 2017;65:793–803.
30. Batt M, Jean-Baptiste E, O'Connor S, et al. In situ revascularisation for patients with aortic graft infection: a single centre experience with silver coated polyester grafts. Eur J Vasc Endovasc Surg 2008;36:182–8.
31. Garot M, Delannoy PY, Meybeck A, et al. Intra-abdominal aortic graft infection: prognostic factors associated with in-hospital mortality. BMC Infect Dis 2014;14:215.
32. Kouijzer IJE, Van der Jagt MFP, Bleeker-Rovers CP, et al. Outcome in patients after autologous femoral vein reconstruction for primary aortic infection and aortic graft infection: a case series. Ann Vasc Surg 2022;83:240–50.