cement in the pelvis or in difficult anatomic positions contributes to the risk of persistent infection after revision arthroplasty has not been studied.

When cement is extruded into the pelvis or difficult anatomic positions during primary arthroplasty, there is a risk of neurological (obturator nerve palsy [3,4], femoral [5] or sciatic nerve involvement [6]), urological (such as a foreign body in the bladder wall [7]) or vascular (with compression of the external iliac vein [8]) complications. During extraction of extruded cement, the risk of these complications may be even greater due to the manipulation needed for extraction.

It is common wisdom and belief among surgeons that foreign material in an infected joint may harbor biofilm formed by the infecting organism. Leaving behind foreign material during resection arthroplasty and debridement, thus, runs the theoretical risk of allowing for biofilm and infection to persist and could therefore potentially jeopardize the success of surgical debridement. The latter dogma has actually never been proven in a conclusive study. It is also known that removal of foreign material, such as cement, from anatomically sensitive and/or inaccessible areas may require a wider surgical approach (such as laparotomy for extruded cement into the pelvis) or manipulation of structures such as organs (e.g., bladder, bowel), vessels (e.g., vena cava or major veins) or nerves (e.g., sciatic or plexus). The manipulation of these structures may threaten the life of the patient and/or lead to catastrophic complications. Thus, we believe surgeons should exercise their wisdom when dealing with patients with PJIs and extruded cement or other foreign materials in anatomically sensitive and/or inaccessible areas.

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QUESTION 4: Does the use of non-antibiotic-impregnated allograft for bone defects during reimplantation increase the risk of recurrence of surgical site infections/periprosthetic joint infections (SSIs/PJIs)?

RECOMMENDATION: There is no evidence to demonstrate that using non-antibiotic impregnated allograft for management of bone defects during reimplantation (following PJIs) increases the risk of recurrence of SSIs/PJIs.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 88%, Disagree: 9%, Abstain: 3% (Super Majority, Strong Consensus)

RATIONALE

Systematic reviews were undertaken using PubMed, Cochrane Library, SCOPUS and Google Scholars databases and relevant papers were reviewed. During review, it became evident that there is a dearth of information directly assessing treatment of PJIs when a non-antibiotic-impregnated allograft was used. Overall, 51 papers were reviewed in full. The evidence is summarized below.

Following the increased popularity of the use of allograft bone in tumor surgery in the 1970s [1], infection has become a major concern. The early reports of infection rates range from 13.2% by Mankin et al. [2] to 11.7% by Lord et al. [3] and were followed by 7.9% in a comprehensive report by Mankin et al. in 2005 [4]. All authors believed that higher rates of infection could be attributed to the disease nature, extent, duration and complexity of the procedures and not related to the allograft itself [2–4].

Tomford et al., in a retrospective study, reviewed 324 patients who received allografts and showed a negligible clinical incidence of infection. The incidence related to the use of large allografts was approximately 5% in bone tumor and 4% in revision of a hip arthroplasty [5]. These rates of infection were not substantially different from those that have been reported in similar series in which sterilized prosthetic devices were used [6]. One of the early reports of allografts in revision total hip arthroplasty (THA) was published by Berry et al. [6]. They used bone allografts in 18 patients during two-stage revision of septic THA failures. At a mean of 4.2 years after reimplantation, only two patients had a recurrence of the infection (11%).

Several retrospective cohort studies have evaluated the use of allograft bone during total hip reimplantation surgery, the second-stage of planned two-stage exchange arthroplasty for infection. The majority of these studies have demonstrated recurrent infection rates of 0 - 9% in cohorts consisting of 11 -27 patients with mid- to long-term follow-up [6-12]. Two studies reported less favorable reinfection rates of 11% (18 patients, mean 4.2-year follow-up) and 14% (57 patients, mean 9-year follow-up) [13,14]. Traore et al. reported a higher rate of 20% for reinfection at mean 3 years [13]. Loty et al. reported a cohort of 90 cases with 8 (9%) reinfections over an unknown follow-up period in one-stage hip revision for infection [14].

Lange et al. performed a systematic review on using bulk allograft for second-stage re-implantation of hip arthroplasty and revealed a reinfection rate of 4 out of 43 (9.3%) at a average follow-up of 6 years. This was comparable to the reinfection rate reported for two-stage revision without using allograft [15]. Alexeeff et al. also had no recurrence of infection in 11 septic failures of THA that underwent two-stage revision THA using massive structural allografts and were followed for an average of 47.8 months [10].

Tsahakis et al. reported on 15 cases that used allograft for revision knee surgery, and of the three infected knees in their case series, there was no recurrence of infection [16]. Wilde et al. performed a retrospective review of 16 revisions total knee arthroplasties (TKAs) with allograft. There were two infected cases and neither of these experienced reinfection [17]. Stockley et al. reviewed 32 deep-frozen irradiated allografts used for the reconstruction of bone defects in 20 knees with an average follow-up of 4.2 years. Three knees developed infection (9.3%) and one of these was a revision for infection. However, they did not believe that the allograft was the source of sepsis [18].

Further reports by Harris et al. [19] (14 patients including 2 infected cases), Mow et al. [20] (15 structural allografts) and Engh et al. [21] (35 allografts) examined revision TKA cases and found no cases of reinfection [19–21]. Ghazavi et al. reported three infections (7%) using bulk allograft in 38 patients, including three infections that underwent revision. Two of the three cases who had previous infections experienced reinfection [22]. In a report by Clatworthy et al. on 52 cases, there were six infections, all of which underwent revision TKA with a bulk allograft. One of the six patients who had a previous infection developed recurrence of infection [23].

English et al. reported their results of using impaction allografting in the second stage re-implantation of 53 infected hip arthroplasties. After a mean follow-up of 53 months, four patients had recurrence of infection (7.5%) [24]. In reports by Dennis et al. (32 allografts) and Garino et al. (eight cases of impaction allografts), there were no infections at final follow-up [25,26].

Hockman et al. reviewed 65 consecutive revision TKAs including 12 infections at a minimum 5-year follow-up. Three of the 12 (25%) previously infected cases developed infections. They concluded that knees originally revised for infection were more likely to fail [27].

Bush et al. reviewed options for reconstructing massive bone loss and recommended against using allograft in some situations, including chronic infections [28]. Backstein et al. reported 68 cases of massive allografts for revision TKA and 11 of these were septic revisions. They found four infections (6.5%). The authors did not include how many of them had surgery for septic revisions. They believed that, because of the large size of the utilized allograft bone and the number of previous surgeries the patients had, the infection rate was modest [29].

Lotke et al. reported on 48 cases including one infection that received impaction allografting in revision TKA. At an average follow-up of 3.8 years, they had two infections (5%) [30]. Bezwada et al. reviewed 11 knees in 10 patients who underwent revision with distal femoral allografts and stemmed components. After a mean follow-up of 42 months they had no infections. They recommended against the use of plate fixation to decrease extensive soft tissue dissection and the risk of infection [31].

Engh et al. reported no cases of reinfection in 49 revision knees with severe tibial bone defects, five of which were revisions for infection [32]. Rudelli et al. reported on 32 loose and infected total hip arthroplasties that underwent revision with a bone graft in a one-stage procedure. After a mean follow-up of 103 months, infection recurred in two (6.2%) cases [33].

Burnett et al. reported on 28 knees that underwent revision TKA with an allograft at a follow-up of 48 months. Only one patient (3.5%), who received a cancellous graft for a contained defect, developed an infection. They did not mention if this was an infected revision [34]. Lyall et al. investigated 15 revision TKA patients, including three revisions for infections with severe tibial bone loss. These patients were followed for a mean of 5.4 years and they found one (6%) recurrence of infection at 3.5 years [35].

Bauman et al. retrospectively reviewed 74 patients (79 knees) who had revision TKAs with structural allografts. Of this cohort, 65 patients (70 knees) were followed for a minimum of 5 years or until revision or death. Five of sixteen failures were secondary to infection (7.1%). Two of these patients had a history of infection and two had local wound problems at the time of revision surgery requiring muscle flap or skin grafting. The authors concluded that the large bulk allografts were more likely to fail secondary to infection or nonunion [36].

In an overview on management of bone loss in revision TKA, Lombardi et al. did not mention infection as a disadvantage (i.e., late resorption, fracture, nonunion, or risk of disease transmission) of using an allograft [37]. Lee et al. retrospectively reviewed 27 patients who underwent two-stage revision arthroplasty using structural allografts to treat massive bone defects in infected hip arthroplasty. After a mean follow-up of 8.2 years, only one patient (3.7%) experienced a reinfection [12].

Richards et al. reported on a cohort of 24 patients reconstructed with femoral head allografts at the time of revision TKA and they compared them to 48 cases without allograft. All reported quality of life scores were higher in the allograft group. They did not observe any failures [38]. Wang et al. reported 28 patients with femoral head allografts for revision TKA at a mean follow-up of 76 months. They had no complications and no infections [39]. Vasso et al. reviewed multiple papers on options for management of bone loss in revision TKA. They concluded that modular metal and tantalum augmentation may considerably shorten operative times with a potential decrease in the incidence of complications, including infection, associated with the use of allografts [40]. In a review of 27 patients who had undergone revision TKA using a fresh frozen femoral head allograft and followed for 107 months, there was one (3.7%) recurrence of infection [41].

Recently, Beckmann et al. performed a systematic review on the treatment of revision TKA with bony structural allografts (overall including 476 cases) and porous metal cones (overall including 223 cases). They compared the failure rates using a regression model with adjustment for discrepancies in follow-up time and number of grafts used (femoral, tibial, or both). They did not separate septic revisions from aseptic revisions, but there was little difference in the infection rates between allograft and porous metal groups [42].

Mancuso et al. also reviewed the available English literature since 2007 on options for reconstruction of bone defects in revision TKA. Infection was reported in 8 of 271 (3%) allografts, 43 of 662 (6%) metal cones and 27 of 901 (3%) sleeves, indicating that the use of allografts did not lead to a higher rate of infection than metal cones or sleeves [43].

Sandiford et al. compared femoral head structural allografts and trabecular metal cones for the management of severe bone defects during revision TKA. They evaluated 30 allografts and 15 metal cones at a mean follow-up of nine years and found no differences in pain, function, or repeat revision. The reason for revision was infection in two patients. They observed no reinfection in either group, although one patient in the allograft group devel-

oped a periprosthetic fracture and developed an infection after treatment of this fracture [44].

Infection is the major cause of failure in revision TKA (44.1%) [32] and the risk is even higher in patients with septic revisions [45]. However, given the absence of any prospective controlled studies, the paucity of comparative studies with control groups and the conflicting data in case series,we could not reach any conclusion regarding the effect of using an allograft on the rate of infection in revision arthroplasty for septic failures.

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