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QUESTION 3: Is irrigation and debridement and exchange of modular parts a viable option for treatment of acute periprosthetic joint infection (PJI) involving oncologic endoprosthesis? If so, what are the indications?

RECOMMENDATION: Yes. Irrigation and debridement with retention of prosthesis (DAIR) is a viable option for management of patients with infected endoprosthesis. The procedure may be offered to patients with superficial early infection (< 3 months), short duration of symptoms (< 3 weeks), well-fixed implants and well-characterized organism demonstrating a highly susceptible pathogen.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Surgical reconstruction using an endoprosthesis after tumor resection is frequently associated with deep surgical site infection that leads to PJI. The prevalence of PJI associated with oncologic endoprosthesis is 7-28% compared to only 1-2% in primary joint replacements. Cancer patients are at a higher risk for developing PJI after receiving an endoprosthesis due to numerous risk factors, which lead to local and systemic immunodeficiency. These risk factors include chemotherapy, radiotherapy, prolonged surgical time, increased bleeding, larger implant surface area and compromised soft tissue envelope.

In case of an infected oncologic endoprosthesis, debridement, antibiotics and implant retention (DAIR) can be performed, especially in early acute infections (< 3 months). If DAIR fails to eradicate the infection, a two-stage revision is necessary. In the literature, two-stage revision is generally reported as a good surgical approach for infection control with a reported success rate of 63-100% [1–6]. Eradication of infection is generally worse after a single-stage revision and, of course, better after an amputation [4,7–9].

In order to optimize the treatment of patients with an infected oncologic endoprosthesis we performed a literature search to assess factors associated with successful eradication of the infection after DAIR. Although various studies assessed infection of oncologic endoprostheses, only few specifically evaluated the efficacy of DAIR [2,3]. We assessed the literature for indications as well as factors that influenced the treatment outcomes of DAIR. Due to the lack

TABLE 1. PubMed relevant search terms

Database	Search Terms	Total
PubMed English Until 01 Feb 2018	PICO 1a: (((((infection) AND ((prosthetic joint OR endoprosthes* OR arthroplast* OR megaprosthes* OR tumourprosthes* OR tumorprosthes*))) AND ((oncolog* OR tumour OR tumor)))) AND ((two stage OR revision))) AND ((antibiotic* OR antimicrobial* OR holiday period))	39
	PICO 1b: ((((((prosthetic joint OR endoprosthes* OR arthroplast* OR megaprosthes* OR tumourprosthes* OR tumorprosthes*))) AND ((oncolog* OR tumour OR tumor))) AND ((two stage OR revision)))) AND ((chemo OR chemotherapy))	67
	PICO 1c: ((((((prosthetic joint OR endoprosthes* OR arthroplast* OR megaprosthes* OR tumourprosthes* OR tumorprosthes*))) AND ((oncolog* OR tumour OR tumor))) AND ((two stage OR revision)))) AND radiotherapy	23
	PICO 1d: ((((((prosthetic joint OR endoprosthes* OR arthroplast* OR megaprosthes* OR tumourprosthes* OR tumorprosthes*))) AND ((oncolog* OR tumour OR tumor))) AND ((two stage OR revision)))) AND ((micro-organism OR bacter* OR culture))	44
	PICO 1e: ((((((prosthetic joint OR endoprosthes* OR arthroplast* OR megaprosthes* OR tumourprosthes* OR tumorprosthes*))) AND ((oncolog* OR tumour OR tumor))) AND ((two stage OR revision)))) AND spacer	19
	PICO 1f: (((((((prosthetic joint OR endoprosthes* OR arthroplast* OR megaprosthes* OR tumourprosthes* OR tumorprosthes*))) AND ((oncolog* OR tumour OR tumor))) AND ((two stage OR revision)))) AND infection)) AND silver	10
	PICO 2: ((((prosthetic joint OR endoprosthes* OR arthroplast* OR megaprosthes* OR tumourprosthes* OR tumorprosthes*))) AND ((oncolog* OR tumour OR tumor))) AND ((DAIR OR debridement OR irrigation OR washout))	74

TABLE 2. Evidence table

Author and Year	Study Type	Patients	Procedures	Follow-up	Major Outcomes
Bus 2017 [17]	Retrospective cohort 2008–2014	N = 47 LUMIC reconstruction for pelvic tumor	* 69% DAIR * 31% implant removal	3.9 years	* 28% had infection. * 69% were successfully treated with DAIR (2). * 31% needed implant removal. Two had amputation, one rotationplasty and one LUMIC prosthesis. * More blood loss was associated with a higher risk of infection; other factors were not associated.
Chambers 1962 [18]	Narrative review	X	X	X	* Article on the bactericidal effects of silver (1f).
Dhanoa 2015 [1]	Retrospective cohort 2007–2011	N = 105 Endoprosthetic reconstruction for tumor	* 54% DAIR * 46% 2-SR	32 months	* 12.4% infection at 0-63 months. * Higher risk after additional procedures (13x), comorbidity, proximal tibia endoprostheses, pelvic endoprostheses and preoperative hospitalization >48 hour. Lower risk with distal femoral prostheses. * 80% of infections had operations >2.5h, compared to 16.3% in non-infections. * 38% Staph aureus, 31% CNS, 23% Klebsiella pneumoniae, 23% Pseudomonas aeruginosa. 38.5% had polymicrobial infection (1d). * 80% of 2-SR were successful; 1 patient had antibiotic suppression. * 43% of DAIR were successful; 2 patients had antibiotics; 2 patients had amputation (2).
Donati 2016 [19]	Retrospective case-control 2005–2016	N = 68 Megaprosthesis reconstruction for proximal femur tumors	X	47 months (12-114 months)	* Overall infection rate 11.8% at mean 25 months: silver 7.9%, control 16.7% (1f). * In late infection, explanted megaprostheses had important degradation of the coating surface (1f). * No differences in functional scores between silver and control (1f). * No local or general signs of toxicity (1f).
Felden 2015 [20]	Prospective cohort 1995–2011	N = 45 Pelvic irradiation before cemented THA	X	51 months (17-137 months)	* Patient survival was 71% at 2y, 52% at 5y and 41% at 10y. * The cumulative probability of revision was 2.2% at 1y, 2.2% at 2y, 8.1% at 5y and 20.2% at 10y. * 6% underwent revision for infection, 1 treated with 2-SR, 2 treated with 1-SR (all successful).
Flint 2007 [2]	Prospective cohort 1989–2004	N = 15 Infection after uncemented Kotz prostheses for bone sarcoma	2-SR	42 months (3-150 months)	* Prosthetic infection occurred at mean 28 months (1-132 months). * 75% CNS, 33% Staph aureus, 8% Pseudomonas aeruginosa, 8% E. coli, 8% Streptococcus viridans (1d). * 73% had second-stage revision: 27% had amputation, 73% with infection control after second-stage. * 60% success with retention of diaphyseal stems; 40% success with removal of anchorage pieces. * No relation between success and anatomical location or infecting organism (1d). * 66% of failures had previous radiation (1c). * In case of infection within 6 months 86% of 2-SR was successful, after 6 months only 25%.

TABLE 2. Evidence table (*Cont.*)

Author and Year	Study Type	Patients	Procedures	Follow-up	Major Outcomes
Funovics 2011 [7]	Retrospective cohort 1982–2008	N = 166 Endoprosthetic reconstruction for tumor	* 83% 1-SR * 8% muscle flap * 8% deceased	47 months (0-365 months)	* Survival rate without infection was 95.9% at 1y, 89.2% at 5y, 89.2% at 10y and 77.8% at 20y. * 7.2% had infection at mean 39 months (0-167 months). * 30% CNS, 30% Staph epidermidis. Polymicrobial infection in 30.8% (1d). * Higher rate of infection in primary tumors, cemented prostheses, pelvic reconstruction, additional operations or radiotherapy (1c). * 63% infection control by 1-SR, 13% additional 1-SR, 25% additional 2-SR.
Gitelis 2008 [21]	No full text	X	X	X	X
Grimer 2002 [3]	Prospective cohort 1989–1998	N = 34 Infection after endoprostheses for sarcoma	2-SR	6-116 months	* Obvious causes of infection included lengthening or rebushing procedures, infected ingrown toenail, chest infection, infected burn blister, infected Hickman catheter and neutropenic septicaemia. * 53% CNS, 32% Staph aureus, 6% streptococci, 3% Enterobacter and 3% Corynebacterium (1d). * 70% had infection control after 2-SR. 6% needed amputation within 6 months. 6% needed additional 2-SR (1 successful, 1 not). 18% had late infections with various treatments. * Overall success rate for controlling infection was 94% at 6 months, 91% at 1 year, 74% at 5 years and 65% at 10 years. * Reinfection occurred in all 3 patients with previous radiotherapy (1c). * Functional outcome after successful infection control was mean 77% MSTS (47-100%).
Hardes 2006 [8]	Retrospective cohort 1992–2003	N = 30 Infection after MUTARS tumor endoprostheses for sarcoma	* 3.3% antibiotics * 10% 1-SR * 80% 2-SR	32 months (3-128 months)	* Infection occurred at mean time 16 months (1-70 months). * 62% CNS, 21% Staph aureus, 14% Enterococcus species. 21% had polymicrobial infections (1d). * 1-SR was successful in 33%, 2-SR in 63% * 33% of 2-SR failures needed amputation, 33% rotationarthroplasty, 11% arthrodesis, 22% retained the spacer (1 died after 4 months, 1 had satisfactory function). * 8.3% needed a change of spacer (1f). * The most important risk factor for failed limb salvage was poor soft tissue. * Chemotherapy, time of occurrence of infection, virulence and type of infection had no influence (1b). * A mean of 2.6 revision operations per patients, mean duration of hospital stay 68 days.

TABLE 2. Evidence table (*Cont.*)

Author and Year	Study Type	Patients	Procedures	Follow-up	Major Outcomes
Hardes 2007 [22]	Prospective cohort 2002–2004	N = 20 Silver-coated MUTARS tumor endoprostheses for metastasis	X	19 months (2-32 months)	* No patients had signs of local or systemic argyrosis (1f). * The mean serum silver concentration was 0.37 ppb preoperatively, 2.80 ppb 2 week postoperatively. Between 2 and 24 months silver concentration varied from 1.93 – 12.98 ppb (1f). * 10 patients showed decreased glomerular filtration rates (1f). * The silver-coating was intact in all patients. Histologic examination showed no signs of chronic inflammation, granulomas or necrotic tissue (1f).
Hardes 2010 [23]	Prospective case-control 2005–2009	N = 51 (74 control) Silver-coated replacement for bone or soft-tissue tumors	Various	19 months (3-63 months)	* 5.9% with silver had infections compared to 17.6% with titanium prostheses, at mean 11 months (1f). * Patients with infection had longer operating time (305 vs. 228 minutes). * 38.5% with titanium prostheses had amputation or rotationplasty for infection, 0% in silver group (1f). * In the silver group 2 were treated with antibiotics alone, 1 had minor revision (one-stage without removal of the stem), all were successful (1f).
Henderson 2011 [24]	Retrospective cohort 1974–2008	N = 2,174 Limb preservation with metallic endoprostheses for tumor	X	X	* 24.5% were considered failures, of which 12% had soft tissue problems, 19% aseptic loosening, 17% fracture, 17% tumor progression, 34% infection. * Infection occurred more often in hinged prostheses than in polyaxial protheses ($p < 0.05$). * Failure incidence decreased over time. The mean time to failure was 47 months. * Literature review of 4359 patients with 29% failures.
Hollinger 1996 [25]	No full text	X	X	X	X
Hsu 1999 [26]	Prospective cohort 1975–1986	N = 38 Limb salvage for tumors needing revision surgery	* 50% revision * 32% amputation * 10% arthrodesis * 8% miscellaneous	51 months	* Indications for reoperation were aseptic loosening (34%), instability (13%), infection (13%), tumor recurrence (13%), fracture (11%) and miscellaneous (16%). * 16% died after revision at a mean of 40 months after revision. * After revision functional results were excellent (12.5%), good (81.3%) or fair (6.25%). * 63% had radiolucent zones immediately after revision. 25% of these developed progressive changes that had an effect on limb function. * Patients with revision had higher survival rates and longer disease-free intervals than patients with amputation ($p < 0.01$). * Overall 18.4% had complications: 5.3% aseptic loosening, 5.3% infection, 2.6% non-union, 2.6% local recurrence and 2.6% instability.
Jacobs 1995 [27]	Retrospective cohort 1983–1991	N = 9 Uncemented THA with previous pelvic irradiation	X	37 months (17-78 months)	* 4/9 radiographic and clinical migrations, 2/4 had revision, of which 1 needed Girdlestone after revision (1c).

TABLE 2. Evidence table (*Cont.*)

Author and Year	Study Type	Patients	Procedures	Follow-up	Major Outcomes
Jeys 2003 [28]	Retrospective cohort 1966–2001	N = 1,261 Endoprostetic replacement	Amputation	5.2 years	* Overall patient survival was 60% at 5 years, 54% at 10 years and 40% at 20 years. * Overall limb survival without amputation was excellent with 91% at 20 years. * Overall risk of amputation was 8.9% of which the reasons were local recurrence (63%), infection (34%), mechanical failure (2%) and persistent pain (1%). * Risk of amputation after infection was 19% compared to 36% for local recurrence. * Time to amputation was a mean of 32 months for infection.
Jeys 2005 [4]	Retrospective cohort 1966–2001	N = 1,240 Prosthetic replacement for bone tumor	* 43% 2-SR * 32% amputation * 24% 1-SR * 2% Girdlestone	5.8 years (0.3-34 years)	* 11% had infection from 1996-2001 3.7%, 14% from 1966-1996. * 88% presented within 2 years after the last surgical procedure. * 48% had Staphylococcus epidermidis, 26% had polymicrobial infection (1d). * Polymicrobial infections did not reduce the rate of successful treatment of infection (1d). * Success rates: amputation 98%, 2-SR 72%, Girdlestone 50%, 1-SR 42%.
Jeys 2007 [29]	Retrospective cohort 1966–2001	N = 412 Endoprosthetic reconstruction for osteosarcoma	X	6.7 years (0-20 years)	* 10% had deep infection at mean time 4.6 months. * 52% had Staph epidermidis, 29% Staph aureus (1d). * There was better survival in patients infected with Staphylococcus (10y survival 92%, mixed organisms 79%, no infection 62.2%, Streptococcus 50%) (1d) * There was no evidence that patients with infections had more effective chemotherapy (1b) * There were more infections after radiotherapy (p=0.02) (1c)
Jeys 2007 [30]	Retrospective cohort 1966–2001	N = 1,254 63 radiotherapy Endoprosthetic replacement for bone tumor	X	5.8 years (0.3-33 years)	* Mean postoperative MSTS function score was lower after radiotherapy (64% vs. 81.3%) (1c) * Risk of infection without radiotherapy 9.8%, preoperative radiotherapy 20.7%, postoperative radiotherapy 35.3% (1c). * Risk of amputation without radiotherapy 7.8%, preoparative radiotherapy 17.2%, postoperative radiotherapy 14.7% (1c). * 10y survival was worse after radiotherapy (29%) than without radiotherapy (58%) (1c).
Jeys 2009 [31]	No full text (chapter book)	X	X	X	X
Kaminsky 2017 [32]	No full text	X	X	X	X
Kim 2007 [33]	Prospective cohort 1997–2003	N = 51 Uncemented THA with irradiation of the pelvis for adenocarcinoma of the prostate	X	4.8 years (2-7.5 years)	* 47% had radiation induced osteonecrosis of the femoral head (1c). * 6% had wound discharge, which healed without surgical treatment (1c). * 2% had deep infection, which required subsequent resection arthroplasty (successful) (1c).

TABLE 2. Evidence table (*Cont.*)

Author and Year	Study Type	Patients	Procedures	Follow-up	Major Outcomes
Lansdown 2010 [34]	Narrative review	X	X	X	* Paper about the mechanisms of absorption and metabolism of silver in the human body, presumed mechanisms of argyria and the elimination of silver-protein complexes in the bile and urine (1f). * Argyria and argyrosis are the principle effects associated with heavy deposition of insoluble silver precipitates in the dermis and cornea/conjunctiva. Argyria is not associated with pathological damage (1f).
Lee 2002 [5]	Retrospective cohort 1985–1998	N = 145 18 infection Tumor prosthesis for bone and soft tissue tumors	* 78% DAIR * 11% 2-SR * 11% 1-SR	44 months (5-136 months)	* 12.4% had infection at mean 8 months (0.5-54 months). * 39% was successfully treated with DAIR or revision; 17% needed arthrodesis and 11% amputation (2). * 100% of 2-SR were successful, 0% of 1-SR were successful. * 33% with uncontrolled infection by DAIR and refused prosthesis removal had suppressive antibiotics. * The knee joint seemed to show poor outcome, but this was not statistically meaningful. * Infection control was poor in cases of cementless fixation ($p < 0.01$). * Chemotherapy gave a higher risk of infection (18.7% vs. 5.6%) (1b). * Soft tissue defects (sinus, pus discharge, wound dehiscence) correlated with poor prognosis ($p < 0.05$).
Li 2011 [35]	Retrospective cohort 1993–2008	N = 53 Endoprosthetic reconstruction for sarcoma	DAIR	10 years	* 1.9% had early infection, successfully treated with DAIR (2). * 5.7% had late infections, all treated with DAIR. One was successful, 2 needed revision (successful) (2). * 7.5% had wound complications requiring repeat surgery (debridement and closure) (2).
Manoso 2006 [16]	Retrospective cohort 1990–2001	N = 11 Infected knee reconstruction after limb-salvage surgery for cancer treated with staged protocol	Staged reconstruction protocol	X	* 82% had chronic infection, with a sinus tract in 45% at mean time 6 months (1-210 months). * 45% had failed DAIRs (2). * 55% had Staph aureus, 27% had Staph epidermidis. In 55%, a single organism caused the infection (1d). * 82% were immunocompromised with the administration of chemotherapy at the time of infection (1b). * All limbs were spared without amputation or flap loss. Overall cure rate was 91%. * Early complications were 2 peroneal palsies and 1 venous flap congestion requiring wound revision. * The mean functional outcome was 23/30 and mean knee range of motion 98 degrees.
Massin 1995 [36]	Excluded	X	X	X	X

TABLE 2. Evidence table (*Cont.*)

Author and Year	Study Type	Patients	Procedures	Follow-up	Major Outcomes
Mavrogenis 2015 [37]	Retrospective cohort 1983–2010	N = 1,161 Megaprosthesis reconstruction after limb salvage surgery for sarcoma	* 83% 2-SR * 12% 1-SR * 5% amputation	Mean 9 years (3-20 years)	* 8.6% had infection at mean time 3.7y. * Most common isolates were Staph epidermidis (47%), Staph aureus (19%) and pseudomonas (6%) (1d). * Overall survival rate of megaprostheses was 88% at 10y and 84% at 20y. * Survival was higher for cementless reconstruction, not different for type of megaprosthesis, site of reconstruction or adjuvant therapy (1b).
Mavrogenis 2011 [38]	Narrative review	X	X	X	* DAIR may be effective in early infections, with short duration of symptoms, well-fixed implants and ideally with well-characterized microbiology demonstrating a highly susceptible pathogen (2). * Success in 2-SR 72-91%, 1-SR 42% and amputation 98-100%. * 2-SR is recommended for persistent infections, antibiotic-resistant pathogens or failed 1-SR. In well-fixed cementless modular prostheses anchorage stems can be retained. * Disadvantages of 2-SR are long hospitalization, increased bone loss, disuse osteoporosis, difficult revision operations and shortening of the affected limb. * Reimplantation should be delayed after completion of chemotherapy (1b). * An antibiotic-loaded cement spacer is essential in 2-SR; added antibiotics should be heatstable (1e). * Most surgeons administer systemic antibiotics 6 weeks, with reimplantation after > 2 months (1a).
McDonald 1990 [39]	Retrospective cohort 1970–1986	N = 304 271 malignant 33 benign Prosthesis or non-biological spacer in limb salvage surgery for primary bone tumors	X	2 years	* 11.8% had infection, 22% of these patients needed amputation. * Adjuvant and neo-adjuvant chemotherapy gave a higher risk of complications (32.8% and 55.4% vs 25.2%). Reconstruction with uncemented prostheses had fewest complications (1b).
Mittermayer 2002 [40]	Excluded	X	X	X	X
Morii 2010 [41]	Retrospective cohort 2000–2008	N = 82 Endoprosthetic reconstruction for knee tumors	X	52 months (9-105 months)	* 17% had infection at mean time 10.9 months. * 50% had Staph aureus, 30% Staph epidermidis and 10% Pseudomonas (1d). * Age, sex, tumor origin, comorbidities, operating time, blood loss, chemotherapy, clean air operating room, extracapsular resection, prosthesis type, number of postoperative antibiotics, posterior muscle flap were not risk factors for infection (1b). * Skin necrosis and surface infection were risk factors for infection.

TABLE 2. Evidence table (*Cont.*)

Author and Year	Study Type	Patients	Procedures	Follow-up	Major Outcomes
Morii 2013 [6]	Retrospective cohort 1995–2009	N = 388 Endoprosthetic reconstruction for knee tumors	* 45% debridement * 14% 2-SR * 10% amputation * 9% 1-SR * 7% soft tissue flap	66 months (5-213 months)	* 14.6% had infection at mean time 13 months. * 47% Staph aureus and 17.5% Staph epidermidis (1d). * Infections were controlled in 84.2% the others had an accepted fistula or suppressive antibiotics. * Patients with diabetes, bone metastasis, lack of gastrocnemius flap coverage and pus required more surgical interventions for infection control. * The most successful therapy was 2-SR (80% success). Therapies with prosthesis removal were more successful than other therapies.
Peel 2014 [9]	Retrospective cohort 1996–2010	N = 121 Tumor endoprostheses surgery	* 53% DAIR * 24% 2-SR * 12% 1-SR * 6% resection * 6% amputation	34 months (17-80 months)	* 14% had infection at median time 18 months * Parenteral antibiotics median 9 days (0-58), 82% received oral combination antibiotic therapy with rifampicin (365 days) (1a). * Success rates: DAIR 75%, 1-SR 100%, 2-SR 50%, resection 0%, amputation 100% (2). * The majority of treatment failures occurred in patients with multi-resistant organisms (1d).
Pilge 2012 [42]	No full text	X	X	X	X
Racano 2013 [43]	Systematic review 1990–2011	N = 4,838 in 48 level IV studies	X	X	* Pooled infection rate was 10% (0-25%). * Most common organisms were Staph aureus and Staph epidermidis (1d). * There is considerable variation in antibiotic regimens. 0-24 hour antibiotic prophylaxis had 13% infection, >24 hour prophylaxis had 8% infection ($p<0.05$) (1a).
Renard 2000 [44]	Prospective cohort 1975–1995	N = 77 Limb saving surgery (50) or ablative surgery (25) for sarcoma	X	97 months (28-271 months)	* 6% had deep infection, leading to amputation in 2/3 cases. * 4% had superficial infection successfully treated with DAIR and gentamicin beads (2).
Sherman 2008 [45]	Excluded	X	X	X	X
Shin 1999 [46]	Retrospective cohort 1970–1990	N = 52 41 malignant 11 benign Limb salvage surgery for musculoskeletal tumor	* 67% revision * 21% amputation * 8% arthrodesis * 2% fibular graft * 2% ORIF	12 years (37-296 months)	* 11.5% had infection. * Functional rating was 63%. Pain 69%, function 53%, emotional acceptance 72%, support 60%, walking ability 62%, gait 54%, hand positioning 66%, manual dexterity 94% and lifting ability 63%. * After revision 33% needed reoperation for complications: 58% aseptic loosening, 25% infection, 17% prosthetic failure and 8% patellar dislocation. * Survival after reoperation was 79% (5y) and 65% (10y).

TABLE 2. Evidence table (*Cont.*)

Author and Year	Study Type	Patients	Procedures	Follow-up	Major Outcomes
Sim 2007 [47]	Retrospective cohort 1996 – 2005	N = 50 Endoprosthetic reconstruction for knee tumors (GRMS)	3 washouts	24.5 months (2-124 months)	* Patients with metastatic disease or pathological fractures did not have higher complication rates. * 12% had deep infection for which patients received multiple washouts and long-term antibiotics (2). * 1/6 had revision; 1/6 had amputation (2).
Wafa 2015 [48]	Prospective case-control 2006–2011	N = 170 Reconstruction with silver-enhanced endoprostheses for several indications	X	12 months	* 11.8% infection in silver group, 22.4% in control group (1f). * Higher incidence of Pseudomonas in the silver group (1d/1f). * 70% of infected prosthesis was successfully treated with DAIR, 31.6% in the control group (1f/2). * 15.3% required implant removal, amputation or antibiotic suppression, 3.5% in the silver group (1f). * 18.8% with adjuvant chemotherapy developed infection (1b). * 15% had relapse infection after 2-SR in the silver group, 42.9% in the control group (1f).
Wirgano-wicz 1999 [49]	Prospective cohort 1980–1995	N = 64 Failed endoprostheses for neoplastic disease	* 75% revision * 25% amputation	2 years	* 13% failed because of an infection. * 50% of infected prostheses had revision with the same prosthesis, 25% with a different prosthesis and 25% underwent amputation. * Patients receiving revision endoprostheses were not at increased risk for a subsequent revision or amputation compared to primary endoprostheses reconstruction.
Zajonz 2016 [50]	Retrospective cohort 1994–2014 Excluded	N = 34 Modular endopros-theses of the lower extremity for infection	X	72 months (6-267 months)	* Reinfection rate after healed reinfection in silver group was 40%, in the non-silver group 57% (1f).
Zajonz 2017 [51]	Retrospective cohort 1994–2011	N = 101 45 tumor Modular endoprostheses of the lower extremity	* 62% 2-SR * 11% resection * 11% arthrodesis * 8% DAIR * 8% amputation	27 months (5-179 months)	* 17.7% had infection (3 early infections, 16 late infections), reinfection rate 37%. * 36.6% CNS, 26.3% Staph epidermidis, 15.8% Staph aureus (1d). * Patients with infection had same age and sex, but higher BMI. * Prosthesis for tumors had fewer infections than other indications (8.9% vs. 21.7%).

of strong levels of evidence published in the form of meta-analyses or randomized controlled trials, we compiled a narrative review discussing various factors associated with infection control in oncologic endoprostheses.

Search Strategy

A literature search was performed in PubMed with relevant search terms on the 23rd of January 2018. The literature search resulted in 83 hits. Additional articles for screening were selected from the reference lists. Articles that were not written in English or did not have full text available were excluded. Twenty-nine articles were excluded based on title and abstract. Another 4 articles were excluded after thorough reading of the full text articles, whereby we included 41 articles in our literature analysis (see Tables 3 and 4).

DAIR procedure is one of the treatment approaches described for PJI of endoprostheses in cancer patients. However, treatment outcomes after DAIR are very variable and unpredictable in an oncology setting. Success rates vary between 39-70% [1,9–12]. Some of the reported factors that are associated with better outcomes after DAIR include superficial early infection, short duration of symptoms, well-fixed implants and well-characterized microbiology demonstrating a highly susceptible pathogen [13–15]. Unfortunately, the studies that reported on DAIR outcomes have very variable periods of clinical follow-up (34 months –10 years).

The most common microorganisms causing infection of oncological endoprostheses are *Staphylococcus aureus* and coagulase negative staphylococci, both account for > 50% of PJI. A large number of the documented infections were also polymicrobial infections accounting for 21-45% of cases [1,4,7,8,16]. There was no difference between monomicrobial and polymicrobial infections regarding outcome [4]. A study by Peel et al. was the only report demonstrating that the majority of infections of endoprosthesis were caused by multi-resistant microorganisms [9]. In one study, the success of outcome for DAIR as well as for two-stage revision for PJI of endoprosthesis did not show any correlation with the infecting organism [2]. It is important to note that the aforementioned results are based on a small number of patients, making generalizability of the findings somewhat limited.

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TABLE 3. Exclusion after reading full text article

Author and Year	Reason for Exclusion
Massin, 1995 [36]	No tumorprosthesis, radiation followed by reconstruction with normal prosthesis, 2 late infections (2yr) of 71 cases, both girdlestone
Mittermayer, 2002 [40]	No information on infection, only on aseptic revision in retrospective cohort
Sherman, 2008 [45]	Case report
Zajonz, 2016 [50]	No tumorprostheses, only modular endoprostheses after PJI

TABLE 4. Exclusion after screening abstract and title

Author and Year	Reason for Exclusion
Aponte-Tinao, 2016 [52]	Does not answer the research question
Ascherl, 2010 [53]	Article in German language
Baker, 2011 [54]	Does not answer the research question
Bielack, 1999 [55]	Article in German language
Bosetti, 2002 [56]	Does not answer the research question
Brigman, 2003 [57]	Does not answer the research question
Buttaro, 2005 [58]	Does not answer the research question
Cho, 2005 [59]	Does not answer the research question
Deelstra, 2013 [60]	Does not answer the research question
Dieckmann, 2014 [61]	Does not answer the research question
Falkinstein, 2008 [62]	Does not answer the research question
Foo, 2011 [63]	Does not answer the research question
Gebert, 2010 [64]	Does not answer the research question
Glehr, 2013 [65]	Does not answer the research question
Gooding, 2011 [66]	Does not answer the research question
Gosheger, 2004 [67]	Does not answer the research question
Goulding, 2017 [68]	Does not answer the research question
Hillmann, 2000 [69]	Does not answer the research question
Ji, 2012 [70]	Article in Chinese language
Kühne, 2003 [71]	Does not answer the research question
Lautenschlager, 1976 [72]	Does not answer the research question
MacMull, 2010 [73]	Does not answer the research question
Mäkinen, 2017 [74]	Does not answer the research question
Malhotra, 2012 [75]	Does not answer the research question
Meek, 2004 [76]	Does not answer the research question
Nazar, 1999 [77]	Article in Polish language
Nebelung, 2000 [78]	Does not answer the research question
Niculescu, 2008 [79]	Does not answer the research question
Nobile, 2015 [80]	Article in Italian language
Pala, 2017 [81]	Does not answer the research question
Radunovic, 2016 [82]	Does not answer the research question
Schmolders, 2017 [83]	Article in German language
Sudmann, 1994 [84]	Does not answer the research question
Vcelak, 2017 [85]	Article in Czech language
Wang, 2011 [86]	Article in Chinese language
Wicart, 2002 [87]	Does not answer the research question
Wilding, 2016 [88]	Does not answer the research question
Wise, 1990 [89]	Does not answer the research question
Yoshida, 2010 [90]	Does not answer the research question

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