

What is debridement, antibiotics, and implant retention in orthopaedic oncology?

A global cross-sectional survey of surgeons' practices and opinions

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Aims

Following resection of a primary bone tumour, reconstruction is commonly performed using either a megaprosthesis or biological reconstruction. Periprosthetic joint infection (PJI) remains one of the most frequent complications. Various treatment strategies exist for PJI, including debridement, antibiotics, and implant retention (DAIR), and single- and two-stage revision, although consensus on optimal management remains elusive. This study aimed to investigate the global practices regarding DAIR in tumour cases through an electronic survey among orthopaedic oncology surgeons.

Methods

A global cross-sectional observational survey study was distributed to 272 orthopaedic oncology surgeons who attended the BOOM Consensus Meeting in January 2024. The survey contained 19 multiple choice questions focusing on DAIR practices. Responses were collected anonymously and analyzed using descriptive statistics.

Results

The survey was completed by 173/272 surgeons (64%) from 44 countries. While 62% (169/272) routinely performed radical soft-tissue debridement in DAIR, only 39% exchanged all modular components, indicating variability in surgical approaches. DAIR was more commonly performed in acute rather than chronic infections, with 55% finding it very useful in acute cases. The use of local antibiotic delivery was supported by 56%, although only 49% found antibiotic cement coatings beneficial. Systemic antibiotic duration post-DAIR varied, with 39% favouring six weeks and 35% preferring three months.

Conclusion

The study highlights global inconsistencies in DAIR practices for PJI in orthopaedic oncology, with financial disparities impacting modular component exchange. Standardized definitions are lacking, and we propose that if only polyethylene is changed, then the procedure is referred to as 'poly exchange'; we recommend defining the procedure as DAIR when extensive debridement, lavage, and removal, wash, and reimplanting of all modular components is done while retaining stable stems, followed by suppressive antibiotic therapy; and finally, we recommend that if all the modular components are changed for new ones, the procedure is referred to as 'DAIR plus'.

Take home message

- Periprosthetic joint infection (PJI) following oncological megaprosthesis reconstruction remains difficult to manage due to inconsistent terminology and absence of standardized treatment guidelines.
- Establishing uniform definitions—differentiating between poly exchange, DAIR, and DAIR-plus—will improve clinical communication, facilitate outcome comparison across centres, and support more consistent treatment strategies.
- Adopting these definitions in future multicentre studies will strengthen evidence-based practice and ultimately enhance patient outcomes in orthopaedic oncology.

Introduction

Following resection of a primary bone tumour, reconstruction with either a megaprosthesis or biological reconstruction (allograft, autograft, or recycled bone) is a commonly employed technique.^{1,2} The preference for reconstruction technique varies depending on patient factors (age, site, tumour type) and surgeon factors (preference, economic, and availability). Megaprosthesis reconstruction is a frequently chosen modality for a variety of reasons, including modularity, stability of the construct, early mobilization, and immediate full weightbearing. Additionally, improvement in long-term implant durability makes this method of reconstruction more appealing.²⁻⁶ Studies have shown good long-term implant survivorship;⁷⁻⁹ however, despite these advances, up to 50% of patients will encounter a complication which may require revision surgery.⁸⁻¹¹ Biological reconstructions also offer a durable reconstruction, favoured in some regions of the world due to lower costs, and in paediatric age groups or diaphyseal tumour locations where preservation of native bone stock is advantageous.¹²

Whichever reconstruction type is used, one of the most common complications is deep infection. In megaprosthesis reconstructions, periprosthetic joint infection (PJI) or type 4 failure in the Henderson classification has a reported incidence of 5% to 30%, leading to significant morbidity, including the risk of amputation, and mortality risk.¹³ In biological reconstruction the incidence has been reported to have similar levels to megaprosthesis reconstruction (4% to 24% and 11% to 26%, respectively).¹⁴ For clarity, deep infection in both biological and megaprosthesis reconstructions will be referred to as 'PJI' throughout this article.

Reasons for increased risk of PJI are multifactorial, and include longer duration of surgery, significant surgical dissection, large bone defects, and immunocompromised status of these patients.¹³⁻¹⁶ Furthermore, the use of adjuvant therapies including chemotherapy and radiotherapy also increases the risk of PJI.¹⁶⁻¹⁸

Within arthroplasty and oncology surgery, various treatment strategies are available to treat PJI including single- and two-stage revision procedures, and debridement, antibiotics, and implant retention (DAIR).¹⁹ Most evidence regarding these treatment strategies is derived from arthroplasty literature, although many publications exist on treating PJI in the oncology setting.^{7,8,20} Controversy exists both in arthroplasty and oncology as to the role of DAIR; however, in arthroplasty it is generally accepted that it is a viable option because of decreased surgical morbidity and financial implications, in comparison to a single- or two-stage revision

Table I. Experiences in orthopaedic oncology.

Questions (number of responses in total)	Responses, n (%)
How long you have been practicing orthopaedic oncology? (n = 173)	
< 5 yrs	19 (11)
5 to 10 yrs	46 (27)
10 to 15 yrs	35 (20)
> 15 yrs	73 (42)
How many bone tumour cases do you treat in a year? (n = 167)	
< 30	41 (25)
30 to 60	48 (29)
61 to 100	32 (19)
> 100	46 (28)
Do you routinely perform non-oncological reconstructive surgeries? (n = 173)	
Yes	83 (48)
Only occasionally	70 (40)
Never	20 (12)
Do you think that peri-implant infections be managed differently in oncological patients? (n = 172)	
Yes	102 (59)
No	16 (9.3)
Only in some cases	54 (31)

in early postoperative infections (within the first few weeks postoperatively), acute haematogenous infections with stable implants, and a good soft-tissue envelope.^{16,18}

In January 2024, the first global consensus meeting (BOOM) on controversies in orthopaedic oncology was held in Birmingham (UK) with 309 delegates from 53 countries. The concept of the international consensus meeting was supported by all major orthopaedic oncology organizations, International Society of Limb Salvage (ISOLS), Musculoskeletal Tumor Society (MSTS), European Musculoskeletal Oncology Society (EMSOS), Asia Pacific Musculoskeletal Tumor Society (APMSTS), and Sociedad Latinoamericana De Tumores Musculosqueleticos (SLATME), but was open for anyone to register. Using a modified Delphi technique, the delegates researched and voted on 41 questions on controversies in chondrosarcoma and PJI in oncology reconstructions.²¹ The periprosthetic infection statements reached with notable agreements, but several statements that did not achieve consensus were on the role of DAIR and prolonged antibiotic use post-revision. The aim of this study, therefore, was to investigate the practices of the delegates with regard to performing DAIR in PJI for tumour cases, via an electronic survey, to highlight questions which could be taken forward to research projects.

Table II. Surgeons' practices and opinion about debridement, antibiotics, and implant retention (DAIR) procedure in oncology.

Questions (number of respondents)	Responses, n (%)
Till when can you perform a DAIR in mega-prosthesis for musculoskeletal oncology cases? (n = 173)	
Up to 3 wks	32 (19)
Up to 6 wks	52 (30)
Up to 3 mths	17 (9.8)
Any time for first-time infections but with stable implants	61 (35)
Other	11 (6.4)
Do you do a radical soft-tissue debridement in DAIR for your oncology cases? (n = 173)	
Yes, always	107 (62)
No, never	8 (4.6)
Sometimes	58 (33)
Do you use local antibiotics in DAIR in oncology? (n = 173)	
Yes, always	97 (56)
No, never	19 (11)
Sometimes	57 (33)
Do you coat implant with antibiotic cement after DAIR? (n = 173)	
Yes, always	36 (21)
Only when there is frank infection	53 (31)
No - it does not help	84 (49)
How long do you use systemic antibiotics following DAIR in oncology? (n = 173)	
6 wks	68 (39)
3 mths	60 (35)
6 mths	11 (6.4)
9 mths	2 (1.2)
Other (please specify)	32 (19)
How many DAIRs would you perform before considering the failure of this alternative and the removal of all implants? (n = 173)	
1	70 (40)
2	84 (49)
3	15 (8.7)
4 or more	4 (2.3)
Do you feel DAIR works in MRSA/Gram-negative/fungal infections? (n = 173)	
I follow the same principles	51 (29)
No, it does not work in these infections and I don't do it	28 (16)
I take my chance and do it	71 (41)

(Continued)

(Continued)

Questions (number of respondents)	Responses, n (%)
I am not sure	23 (13)
Do you do DAIR in chronic infections? (n = 172)	
Yes – always on first presentation	16 (9.3)
No	97 (56)
Yes – only if stem is well fixed	50 (29)
I am not sure	9 (5.2)
Do you believe a two-stage revision is harder or less effective after a DAIR in oncology? (n = 173)	
Yes, always	16 (9.3)
No, never	68 (39)
Sometimes	83 (48)
Other (please specify)	6 (3.5)

MRSA, methicillin-resistant *Staphylococcus aureus*.

Methods

Following the BOOM meeting, a working group was formed from a geographically diverse range of orthopaedic oncology surgeons to prioritize 19 questions exploring their practice, opinions on the usefulness of DAIR, and what steps within the DAIR process they routinely use. The questions were multiple choice in format. The customized cross-sectional survey was disseminated to 272 orthopaedic surgeons who had attended the BOOM meeting. Attendees were solicited to participate using a web-based survey tool (Survey Monkey, USA), and were prompted via email and a supplemental reminder WhatsApp (WhatsApp, USA) message where possible. The survey was open for delegates to take part in for one month, from 1 to 30 September 2024. The respondents were required to identify themselves in order to prevent multiple entries, and this was cross-checked with the distribution list. However, all responses were anonymously collected and analyzed.

The questionnaire was composed of two sections, focusing mainly on the participating surgeons' experience in orthopaedic oncology and their perceptions and experiences about DAIR in the management of PJI (Tables I and II). The survey did not require the completion of all questions before submission; however, missing data were found only in 0.4% (11/272) of responses.

Statistical analysis

Data was analyzed using SPSS software version 27 (IBM, USA) and descriptive statistics were used to summarize all the responses. All responses from the participants are presented in frequencies, percentages, and bar charts.

Results

The survey was completed by 173/272 delegates (64%) from 44 countries. The main regions represented were Europe 59/173 (34%), followed by Asia 47/173 (27%), South America 28/173 (16%), North America 19/173 (11%), Australasia 9/173 (5%), the Middle East 6/173 (3%), and Africa 5/173 (3%).

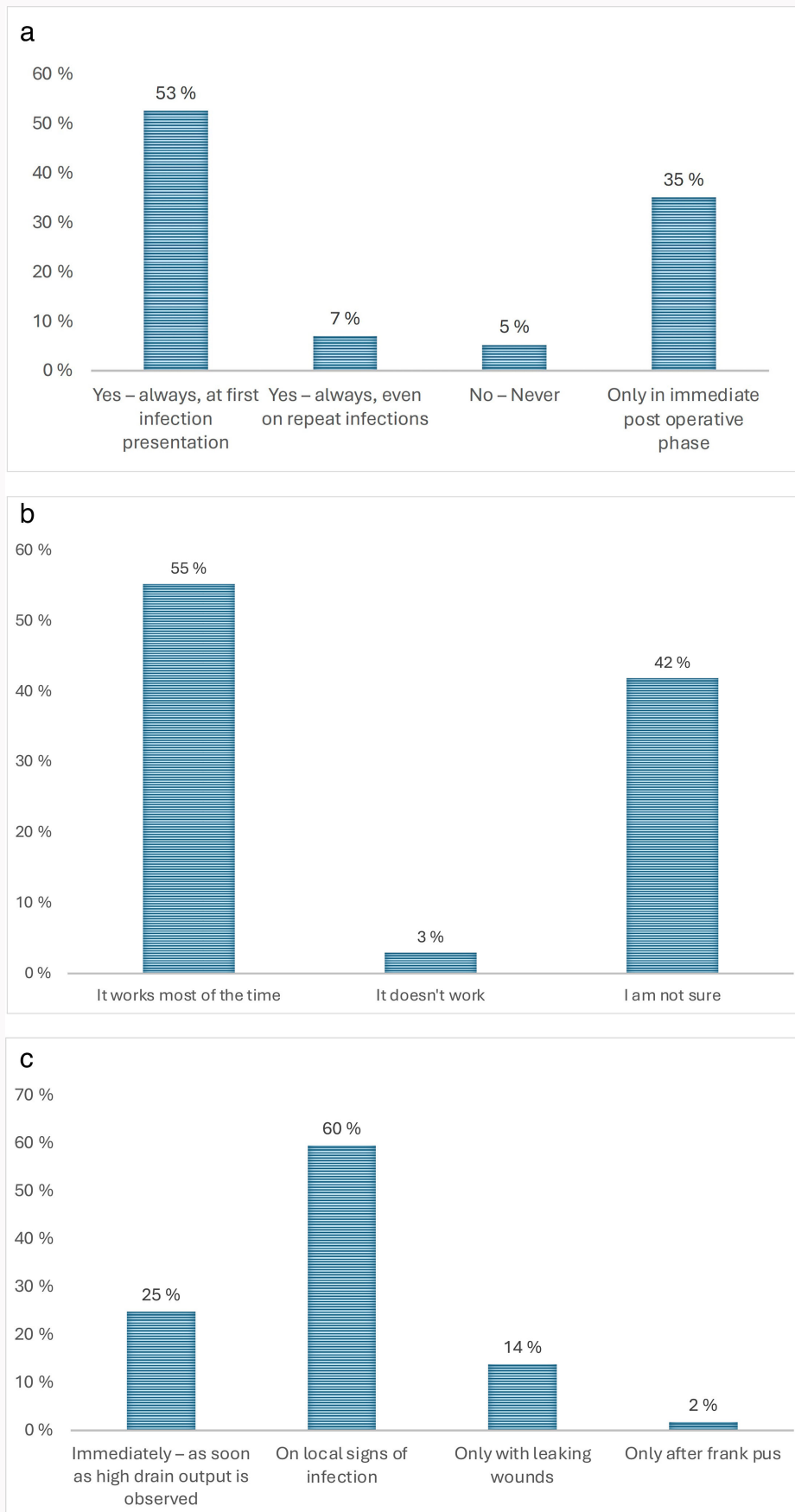


Fig. 1

Perception about the use of debridement, antibiotics, and implant retention (DAIR. a) Do you perform DAIR in suspected infection in biological reconstruction? b) Do you think DAIR works? c) When should DAIR ideally be done?

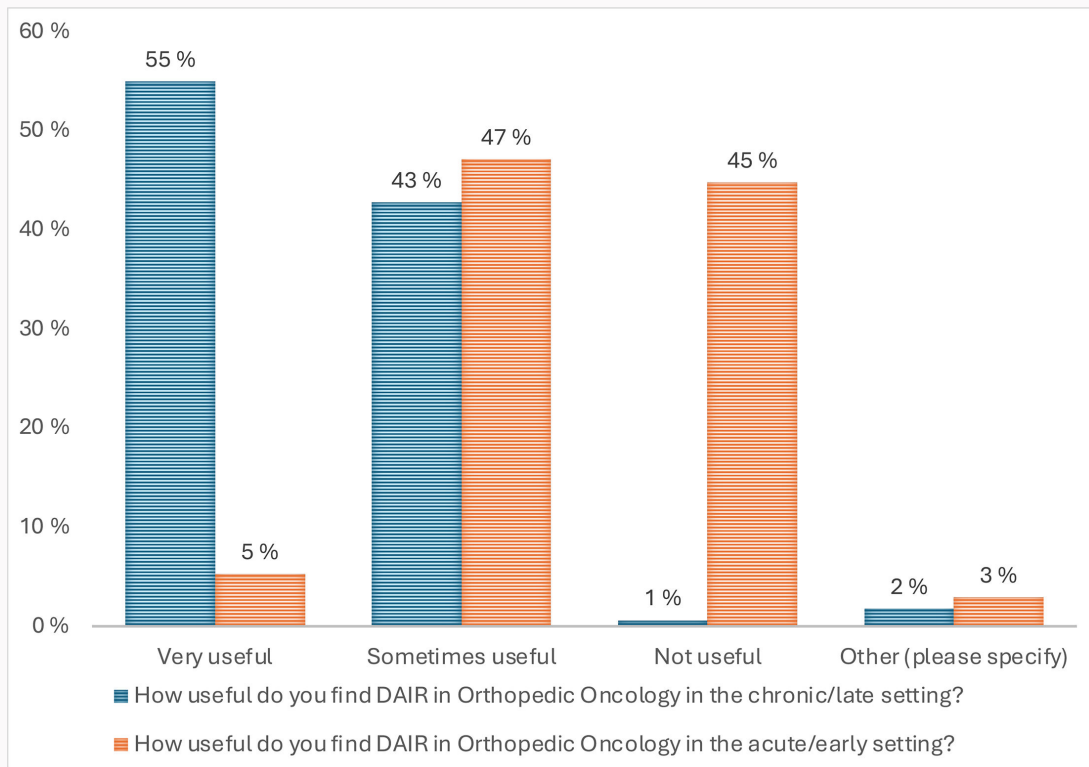


Fig. 2 Usefulness of debridement, antibiotics, and implant retention (DAIR) procedure in acute and chronic settings.

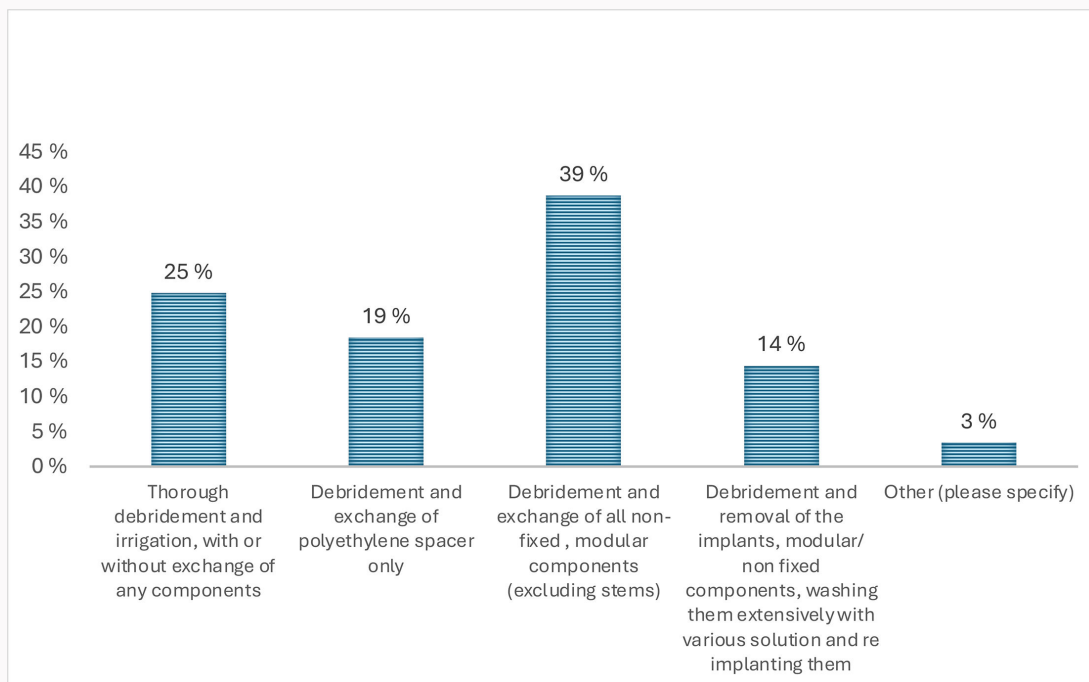


Fig. 3 Debridement, antibiotics, and implant retention (DAIR) procedure for early periprosthetic infection in megaprosthesis reconstruction.

Experience in orthopaedic oncology

Overall, 73/173 of the surgeons (42%) had 15 or more years of experience in orthopaedic oncology, while 46/173 (27%) had five to ten years of experience. A total of 48/167 of the surgeons (29%) treated between 30 and 60 musculoskeletal

oncology cases annually, while 46/167 (28%) handled more than 100 cases (Table I). Along with oncological surgeries, 83/173 surgeons (48%) also routinely performed non-oncological reconstructive surgeries. In total, 102/172 surgeons (59%) believed that peri-implant infections are managed differently

Table III. Proposed definitions for surgical procedures attempted to salvage implants in periprosthetic joint infections for megaprosthesis in oncological cases.

Name	Definition
Poly exchange	Exchange of polyethylene only, without aggressive soft-tissue debridement
DAIR	Aggressive soft-tissue debridement, lavage, removal with washout, and reimplantation of all modular components while retaining stable stems
DAIR plus	Aggressive soft-tissue debridement, lavage, and removal with exchange of all modular components while retaining stable stems

DAIR, debridement, antibiotics, and implant retention.

in oncology patients. However, 54/172 (31%) thought that they should be managed differently only in certain cases. It is of particular note that 107/173 (62%) reported that they routinely perform aggressive soft-tissue debridement in DAIR for their oncology cases (Table II).

Practices and opinions about DAIR procedure in orthopaedic oncology

Overall, 90/171 (53%) responded that they will always perform a DAIR for first infection presentation at any time in biological reconstruction cases, while 60/171 (35%) will perform it only in the immediate postoperative phase. Only 12/171 (7.0%) would perform it always in cases of repeat infections (Figure 1a). A total of 95/172 (55%) believed that DAIR works most of the time, whereas only 5/172 (2.9%) thought that it does not work, and the others remained unsure about its usefulness. More than half of the respondents 103/173 (60%) agreed that DAIR should be performed straight away on appearance of local signs of infection (Figure 1b).

When asked about the usefulness of DAIR procedure in acute and chronic settings, 95/173 surgeons (55%) found it very useful in their experience in an acute setting, while 81/172 (47%) found it useful sometimes in a chronic setting; 77 (45%) did not find it useful for chronic infected oncology cases (Figure 2).

Approximately 67 out of 173 respondents (39%) believed that DAIR should include thorough debridement and exchange of all non-fixed modular components, excluding stems. Meanwhile, 43/173 (25%) supported thorough debridement and irrigation with or without component exchange, and 32/173 (19%) preferred debridement with exchange of the polyethylene insert only (Figure 3).

Regarding acceptable timing for DAIR in oncology cases, 61/173 surgeons (35%) reported that they would perform DAIR at any time for first-time infections if the implant was stable. In contrast, 52/173 (30%) considered DAIR appropriate up to six weeks postoperatively, and 32/173 (19%) limited its use to within three weeks (Table II). A majority of respondents (97/173 (56%)) supported the use of local antibiotic delivery during DAIR in oncology, while 57/173 (33%) used it occasionally. Almost half (84/173 (49%)) did not find antibiotic cement coating of implants helpful for DAIR

procedures. Systemic antibiotics would be used for six weeks and three months by 68 (39%) and 60 (35%) respondents, respectively. Notably, 71 surgeons (41%) indicated that they would still attempt DAIR for infections caused by methicillin-resistant *Staphylococcus aureus* (MRSA), Gram-negative bacteria, or fungi, whereas 51/173 (29%) adhered to a similar treatment approach in these challenging cases.

When considering failure as an endpoint for DAIR, almost half of the surgeons (84/173 (49%)) would prefer to perform the DAIR procedure twice before considering failure and removal of implant, while 70/173 (40%) would perform it only once and 15/173 (8.7%) would perform it at least three times. Regarding two-stage revision after DAIR in oncology cases, 83/173 (48%) of the respondents indicated that sometimes it is harder and less effective, whereas only 16/173 (9.3%) found two-stage revision harder after DAIR (Table II).

Based on the survey findings and observed variation in surgical practices, a summary table was created to define and distinguish between poly exchange, DAIR, and DAIR plus procedures, providing a structured classification to guide clinical reporting and research (Table III).

Discussion

Reconstruction following large resections in musculoskeletal oncology remains challenging. Megaprosthesis reconstruction offers advantages such as modularity, stability, and early mobilization, whereas biological reconstruction (autograft/allograft) preserves bone stock. The commonest complication or mode of failure for orthopaedic oncological reconstruction cases continues to be PJI.^{14,18} Various treatment strategies are used for PJI, including DAIR, single-stage, and two-stage revision, with different studies reporting variable outcomes. There are multiple factors – host, implant, and surgeon – that may affect the outcome of these procedures.^{10,16,22–26}

PJI is a significantly greater risk in orthopaedic oncological reconstructions, whether with megaprosthesis or biological reconstruction, when compared with normal arthroplasty procedures. This increased infection risk, when combined with the importance of avoidance of a break in chemotherapy regime (which, again, has been shown to impact patient survival), means that a fast, effective rationale to treat PJI is vital. DAIR is an attractive option, but lacks consensus on its definition and effectiveness. In addition to megaprosthesis, the extent and definition of DAIR for PJI in primary arthroplasty in the literature is also vague, and disparity in practices has been reported.^{11,14–16}

The BOOM Consensus meeting revealed considerable debate around the role of DAIR, with differences in practice regarding modular component exchange—40% of the surgeons advocate full arthroplasty, while 25% of the surgeons favour antiseptic washing. As megaprotheses are costly and pose a financial burden on the health system, the extent and definition of DAIR also varies globally, when considering exchange of modular components. Global disparities, particularly financial limitations in some countries, strongly impact DAIR procedures, often hindering the routine exchange of modular components. As a result, defining DAIR universally remains challenging, as regional economic constraints shape surgical decision-making and treatment

feasibility.^{25–31} The role of exchanging modular components instead of chemical irrigation has been supported by a study from Gonzalez et al.¹⁸ they showed limited evidence that DAIR plus (exchange of all modular components except stems) achieves similar success rates to two-stage revision, whereas DAIR without full component exchange results in higher failure rates.

In the arthroplasty literature, the surgical technique for DAIR involves extensive surgical debridement and lavage of infected tissues, removal of any biofilm and all modular components, followed by long-term suppressive therapy with antibiotics.^{16,18,19} Our study, encompassing a global orthopaedic oncology audience, reveals significant variability in DAIR practices. While 59% of respondents believe that PJI in musculoskeletal oncology differs from primary arthroplasty, only 62% perform aggressive soft-tissue debridement. Notably, just 39% endorse full modular component exchange (excluding stems), underscoring global inconsistencies in PJI management. Our survey also showed that 40% would do only one DAIR before considering the procedure to have failed, whereas almost 50% of the surgeons would perform DAIR twice before removing all implants in case of failure.

The lack of standardized terminology in infection management of endoprosthetic reconstruction limits comparative research, introduces bias in retrospective analyses, and hinders the development of clinical guidelines. Therefore, we advocate for a simplified yet structured classification system to improve consistency in reporting, and facilitate future outcome studies. We propose a new classification framework specific to endoprosthetic reconstructions: 'DAIR plus' corresponds to the conventional definition of DAIR in conventional revision arthroplasty, involving removal and exchange of all modular components; 'DAIR' refers to a procedure in which modular components are reimplanted following extensive debridement and lavage; and 'poly exchange' describes a minimal intervention strategy, where only the polyethylene insert is replaced without thorough debridement or lavage, often chosen as a cost-effective alternative in low-resource settings or in patients with limited physiological reserve. The usefulness of different management strategies depends not only on financial resources, but also on the aggressiveness of the treatment, which must take into consideration the patient's clinical situation during the course of the disease—such as whether they are undergoing postoperative chemotherapy or have a limited life expectancy due to distant metastases. In these patients, overall survival might take precedence over limb salvage and infection eradication. However, this classification aims to distinguish between procedures of differing complexity and intent, thereby enabling more accurate interpretation of outcomes and more meaningful comparison across studies.

In the literature, local antibiotic deliveries, such as using calcium sulphate as a carrier for vancomycin, have been shown to achieve biofilm-active concentrations for at least two weeks, providing targeted antimicrobial action at the infection site.³² However, in a recent study, Sigmund et al.³³ showed that DAIR with antibiotic-loaded calcium sulphate beads did not improve outcome in early postoperative and chronic PJIs, but reduced the reoperation rate in acute haematogenous infections with similar results compared with early postoperative PJIs. The opinions on local antibiotic delivery

in our survey were divided, with only half of respondents finding it beneficial and using local antibiotics always while doing DAIR. Similarly, systemic antibiotic duration post-DAIR remains controversial, with equal distribution between six weeks and three months, mirroring arthroplasty data where shorter durations correlate with early failure.^{22,31}

Along with all the above factors, the success of DAIR also depends on the causative organism for PJI, its virulence, and susceptibility to antibiotics.^{2,17} The opinions in our survey showed that 80% (218/272) of the surgeons follow the same DAIR principles when the causative organism was known to be MRSA, Gram-negative bacteria, or fungus.

There are certain limitations of this study. First, a key limitation is the lack of a standardized definition of DAIR in orthopaedic oncology. Respondents likely interpreted the term based on personal or institutional practices, introducing variability into the survey results—particularly in responses shown in [Figure 3](#). This highlights the need for consensus on terminology to improve comparability and interpretation of clinical decision-making across centres. Second, we surveyed physicians rather than conducting an in-depth analysis of individual patient data; our findings could be influenced by recall bias and may not accurately reflect the actual practices of individuals and regions. Third, there may also be potential selection bias due to the inclusion of more academically inclined or engaged members of the orthopaedic oncology community. Fourth, multiple choice questions may not fully capture the nuances of decision-making in complex oncological infections. Open-ended responses or case-based vignettes might have yielded richer data. Finally, surgeons who feel strongly about DAIR (positively or negatively) may have been more likely to respond, skewing the data towards more polarized viewpoints.

In conclusion, due to the inconsistencies in defining the treatment and ambiguity in the literature,^{10,16,21–25} managing these complex patients with PJI according to any specific guidelines or standards becomes challenging. Based on the results of our survey, and compared with the variations in DAIR in arthroplasty data, the findings highlight the need for a standardized DAIR definition in oncological megaprosthesis reconstructions. Therefore, we propose that, if only polyethylene is changed then the procedure is referred to as 'poly exchange'; we recommend defining the procedure as 'DAIR' when extensive debridement, lavage, and removal, wash, and reimplanting of all modular components while retaining stable stems is done, followed by suppressive antibiotic therapy; and if all the modular components are changed for new ones, the procedure is referred to as 'DAIR plus'. In the future a multicentre prospective study is needed to establish standardized DAIR guidelines for PJI management in orthopaedic oncology.

Supplementary material

List of the BOOM Consensus Meeting participants.

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