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Research Article

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Impact of Antimicrobial-Impregnated Dressings on the Rate of Periprosthetic Joint Infections in Primary Joint Arthroplasty Surgeries of the Hip and Knee

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ABSTRACT
Periprosthetic joint infections (PJIs), are a serious complication following total joint arthroplasty (TJA) of the hip and knee. Antimicrobial-impregnated dressings (AMIDs) are emerging as an adjunct measure to reduce microbial growth at the surgical site. This literature review examines the evidence regarding iodine and silver AMIDs in primary TJA of the hip and knee. Evidence indicates that use of AMIDs can be highly beneficial in high-risk infection patients, especially silver-based AMIDs to reduce the incidence of PJIs. Studies showed silver- and iodine-based AMIDs have comparable effects on healing wounds colonized by *Staphylococcus aureus*. There remains debate regarding the appropriate clinical setting to utilize AMIDs, as they are generally more expensive than traditional dressings. Multiple studies demonstrate the utility and cost-effectiveness of AMIDs in reducing the risk of PJIs, including one study estimated that using AMIDs, particularly with silver, could reduce the nationwide cost of PJIs from $500 million to $125 million. Silver-impregnated dressings were more expensive than iodine ($38.05-40 versus $18.07 on average), but there is variability in costs and product availability depending on facility contracts, among other factors. More research is needed to investigate optimal composition of AMIDs, the appropriate patient populations to utilize AMIDs in, and if it is cost effective for routine use in primary TJA of the hip and knee.

Keywords: Orthopedic Surgery, Total Joint Arthroplasty, Postoperative Wound Management, Antimicrobial Dressing, Periprosthetic Joint Infection

List of Abbreviations

AAR	:	Absolute risk reduction
AMID	:	Antimicrobial-impregnated dressing
EPS	:	Extracellular polymeric substances
NNT	:	Number needed to treat
PJI	:	Periprosthetic joint infection
SSI	:	Surgical site infection
THA	:	Total hip arthroplasty
TKA	:	Total knee arthroplasty
TJA	:	Total joint arthroplasty
VAS	:	Visual analog scale

Introduction

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are increasingly performed to restore mobility, reduce chronic pain, and improve the quality of life in patients with advanced joint disease, such as osteoarthritis. The demand for total joint arthroplasty (TJA) is rising with increases in the United

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States' aging population. In an article published by the Journal of Bone and Joint Surgery, it is estimated that, by 2040, THA and TKA surgeries are projected to grow 176% and 139%, respectively [1]. While TJA generally have high success rates and excellent patient-reported outcomes, they carry a significant risk of complications, with periprosthetic joint infections (PJIs) being the one of the most severe [1,2]. PJIs are postoperative complications that can result in extended hospital stays, long-term antibiotic therapy, and revision surgery including original implant removal. In an article evaluating the cost effectiveness of silver-impregnated wound dressings, Toppo et al. described the burden PJIs have on a patient as "one of the most medically and financially onerous complications after TJA" [3]. Complications of TJA, due to microbial burdens like biofilms, regularly involve extensive treatment plans contributing to increased costs and burdens on the patient. In a 2005 article published in Clinical Orthopaedics and Related Research, Dr. Costerton and colleagues discuss the difficulty in treating PJIs due to the complex microbacterial biofilm matrix formed by bacterial colonies that contributes to its antibiotic resistance [4]. As a result, PJIs contribute to higher healthcare costs from increased hospitalizations and interventions, surgical failure rates, and patient mortality [1,2]. In a recent 2024 study, Mundi et al. illustrated that poorly controlled comorbidities led to higher rates of PJIs, along with increased mortality rates in patients undergoing TJA [5]. Dr. Patel reports a five-year mortality rate of 21%, with 45% at 10 years following hip PJIs [6]. These reports emphasize the severity of PJIs while emphasizing the need to take prophylactic measures to reduce the risk of PJIs. In a study of 53,252 Medicare patients, Bozic et al. found the "two-year risk of PJI and 90-day risk of mortality following THA were 2.07% and 1.30% respectively" [2]. Patients with diabetes, renal disease, and immunocompromised patients are some at the highest risk for PJIs, demonstrating the need for postoperative infection prevention strategies, which may include wound care outside of standard guidelines [2-6].

Need for Infection Prevention

With the rising number of TJAs performed, it's imperative that orthopedic surgeons adhere to strict infection prevention strategies. Standard preventive procedures include perioperative antibiotic use, antiseptic skin preparation, and sterile surgical techniques. Postoperative wound care, including the use of antimicrobial-impregnated dressings (AMIDs), is a crucial component of decreasing the risk of PJIs. Several dressings, such as silver- or iodine-based dressings, have emerged as a prophylactic measure to reduce surgical site infections and improve wound healing in TJA patients. In an article examining the impact of silver-impregnated wound dressings on PJIs, Grosso et al. reports TKA infections rates range from 1% to 4%, THAs range from 0.59% to 2%, but these rates dropped to 0.33% when patients used a silver-impregnated wound dressing [7]. Although infections after joint arthroplasty are uncommon, they cause devastating consequences to the healthcare system and patient quality of life when they occur. A New England Journal of Medicine article reports that the treatment of PJI for the hip and knee costs $89,000 and $116,000, respectively [6]. These costs typically do not account for the loss of income while off of work, the mental health considerations of the patient, and the social effects on the patient's family or those who may help care for them.

Antimicrobial-Impregnated Dressings Can Lower Healthcare Costs

With the great burden PJIs place on the healthcare system and the individual patients, it is necessary to investigate the cost effectiveness of preventative adjuncts. While AMIDs are generally more expensive, they are cheaper than the cost of PJIs. Silver-impregnated dressings are some of the most expensive AMIDs at approximately $38, while iodine drapes are less expensive at $18, with some variability depending on facility and contracts [3,7,8]. Grosso et al. reports that the traditional Xeroform and standard gauze dressings are normally priced at $2-3 [7]. While a more expensive dressing may not be necessary for all patients, certain patient populations, such as those with diabetes, prior history of surgical site infections, or the immunocompromised, are at a higher risk for PJIs. For these high-risk patients, the higher price of AMIDs could be justified when considering their reduction of complications. When the immense cost of PJIs is taken into account, widespread use of AMIDs should be considered by orthopedic surgeons for THA and TKA patients.

This literature review aims to examine the effectiveness of AMIDs in reducing PJIs in primary TJAs of the hip and knee. This review evaluates current evidence on infection rates, wound healing, and clinical outcomes of AMIDs. Most importantly, this review analyzes the evidence as to whether antimicrobial dressings would be an effective adjunct in reducing PJIs following THA and TKA. Understanding their role in postoperative wound care can provide new opportunities to decrease healthcare costs, reduce PJI incidence, and optimize patient outcomes in orthopedic surgery.

Methods

Five reviewers independently searched studies pertaining to antimicrobial dressings in TJA including PubMed and Google Scholar. Keywords used when conducting searches included "antimicrobial dressing," "total joint arthroplasty," and "perioperative joint infection." Only studies evaluating antimicrobial dressings regarding hip or knee arthroplasty were included. Studies were excluded if they were published before 2000, focused on other orthopedic procedures rather than total joint arthroplasty of the hip or knee, or did not assess outcomes of antimicrobial dressings in reducing periprosthetic joint infections. No meta-analysis was conducted.

Results

Pathophysiology and Risk Factors of Periprosthetic Joint Infection

Multiple intricate mechanisms have been proposed in the eradication of periprosthetic joint infections (PJIs), leading to difficulty in treatment. One notable mechanism is the formation of biofilms, a large colony of bacteria with an ability to attach to various surfaces, protect themselves, and disperse [9]. Bacteria utilizing biofilms benefit from the ability to thrive in diverse environments and resist elimination [10,11]. Though the exact mechanisms of adherence are not fully known or consistent across the numerous bacterial species, it is generally accepted that the initial interaction between bacteria and a foreign surface is mediated by flagella, which utilize surface charge attraction, hydrophilic and hydrophobic interactions, or specific attachment by fimbriae to mediate an attachment [9,10]. After the bacteria is introduced to an environment potentially suitable for colonization, it engages in rapid replication and forms extracellular polymeric substances (EPS) [9,12-14]. The EPS is a mixture composed of various polysaccharides, extracellular DNA, proteins, lipids, biosurfactants, flagella, and pili [9,12-14]. Of these components, extracellular DNA has been the most consistent commonality in various types of biofilms in humans [14]. As the bacteria form a biofilm, growth is slowed down to develop layers of the biofilm [11]. The formation of layers is a key factor to biofilm's resistance to antimicrobial substances. The outer layer of a biofilm plays a role in microbial resistance primarily due to a low rate of growth in the outermost layer [15]. This can lead to lower efficacy of antimicrobial substances that aim to disrupt bacterial growth. Biofilm microorganisms are up to 1000 times more resistant to growth-dependent antimicrobial agents than free-floating bacteria [16]. Understanding the mechanisms of infectivity and antimicrobial treatment is essential to effective treatment and prevent of PJIs. The etiologic agents of PJIs include, but are not limited to, various microorganisms, such as Staphylococcus epidermidis, Staphylococcus aureus, Streptococcus, Enterococcus, Cutibacterium acnes, and Enterobacterales, which could occur in combination or individually [17-19]. The type of infecting organism is influenced by many factors including the affected joint, implant selection, sterilization techniques, and comorbidities.

As the number of orthopedic arthroplasty surgeries increase, physicians must remain informed of the various risk factors to effectively mitigate the risk of PJIs. Risk factors for PJIs can be broadly categorized as surgical, healthcare-associated, and patient-specific factors including older age, tobacco and alcohol use, intravenous drug use, poor oral hygiene, malnutrition, inadequate preoperative glycemic control, and obesity [16,20]. Additionally, medical comorbidities resulting in immunosuppression also increase the risk of infection, such as poorly controlled diabetes mellitus, liver disease, chronic kidney disease, HIV-infection, inflammatory arthropathies, and use of immune-modifying medications [20]. Surgical risk factors can include prolonged surgery time, poor sterilization techniques, and revision surgeries in the same region of the body. These factors can elevate the risk of exposure to infective agents, such as through direct microbial seeding or hematogenous spread to the joint, which can lead to PJIs.

Healthcare-associated risk factors include pre-surgical treatment, preoperative hospital stay, choice of antibiotic prophylaxis, and postoperative care [21]. Patients receiving intra-articular injections of glucocorticoids, hyaluronic acid, or anesthetics within three months preceding arthroplasty can be at higher risk of infection [20]. Additionally, longer hospital stays prior to surgery can increase exposure to nosocomial infections and colonization [22]. To effectively reduce infection risks in specific populations, appropriate selection of antibiotic prophylaxis and dosage is crucial [4]. Lastly, postoperative wound management with correct wound cleaning instructions and surgical site monitoring is important for infection detection [19]. Discussion of efficient wound-related management to reduce PJIs is an essential component of risk mitigation.

Antimicrobial-Impregnated Dressings Mitigate the Burden of Joint Infection

Antimicrobial-impregnated dressings (AMIDs) have demonstrated increased utilization in orthopedic procedures, particularly in total joint arthroplasty (TJA), where infection prevention is critical to improve patient outcomes [7]. Various types of antimicrobial dressings exist with each offering unique advantages depending on clinical scenarios and patient-specific factors. Adhesive dressings stick directly to the patient's skin and establish a physical barrier between the surgical site and the external environment, which can minimize bacterial contamination through direct contact. In TJA, silver-containing adhesive dressings have been particularly effective in reducing superficial wound complications and preventing infection, leveraging silver's broad-spectrum antimicrobial properties [23]. The specific combination of antimicrobial properties and dressing type is clinically significant when selecting dressings aimed at preventing periprosthetic joint infections (PJIs).

Silver-impregnated dressings achieve their antimicrobial effect through multiple mechanisms, such as silver ions disrupting bacterial cell membranes, interfering with metabolic processes, and inhibiting DNA replication [24]. These mechanisms collectively lead to bacterial cell death [24]. Due to silver's broad-spectrum efficacy against both gram-positive and gram-negative organisms, it is particularly valuable in orthopedic surgery, where contamination risk or resistance to conventional antibiotics is of concern [24]. Therefore, silver dressings are often employed postoperatively in TJA, especially in high-risk patients, such as those with chronic kidney disease or immunodeficiencies.

Similarly, iodine-based dressings have significant clinical applications in orthopedics. Dressings containing povidone-iodine interact directly with amino acids and fatty acids within microbial cell membranes, causing rapid structural and functional damage, effectively reducing microbial colonization, and exhibiting anti-inflammatory properties by decreasing reactive oxygen species [25]. Alternatively, cadexomer iodine dressings manage wound exudates through absorption, expanding into a gel that aids debridement while releasing iodine in a controlled manner, reducing the risk of iodine toxicity [26]. There is widespread use of iodine AMIDs in wound care, but their use postoperatively has limited prior investigations. Due to the cost effectiveness and dynamic properties of cadexomer iodine dressings, more research should be conducted to determine their efficacy when compared to the standard of care in infection prevention after TJA.

The types of antimicrobial agents used include occlusive, adhesive, non-adherent, hydrofiber, and foam dressings [23]. Adhesive dressings effectively adhere to surgical sites, providing physical barriers against external contamination, which significantly decreases bacterial entry risks postoperatively [23]. Non-adherent dressings, such as polyurethane foams, offer ease of removal, minimal pain, and optimal moisture management [27]. These features are crucial in orthopedic procedures, as they minimize trauma to fragile postoperative wounds, reduce patient discomfort, and aid rapid re-epithelialization [27]. Hydrofiber dressings, primarily composed of sodium carboxymethylcellulose, absorb wound exudates and convert to a gel, maintaining an optimal moist environment conducive to healing [27]. Silver-containing hydrofiber dressings have been found to reduce the frequency of dressing changes, superficial infections, and other complications like blister formation after

TJA [28]. Silver-impregnated occlusive dressings have proven highly effective in postoperative wound management following TJA, providing excellent wound support, superior exudate absorption, and controlled antimicrobial release, which can reduce the incidence of acute PJIs [7]. These dressings significantly decrease the incidence of postoperative wound complications and surgical site infections, ensuring optimal wound healing [29]. An important clinical consideration in managing PJIs is the type of dressing used and whether it has an antimicrobial-impregnated substance. Choosing the most suitable dressing involves consideration of wound characteristics, anticipated exudate levels, patient comfort, and overall infection risk. Integrating evidence-based selection of antimicrobial dressings into postoperative care protocols enhances patient outcomes and minimizes complications following TJA.

Table 1: Comparison of iodine and silver antimicrobial-impregnated dressings and drapes

Antimicrobial-impregnated Material Source	Mechanism of Action	Average Cost	Potential Benefits	Potential Complications or Side Effects
Iodine	Iodine interacts directly with amino acids and fatty acids in the bacterial cell membrane. This interaction causes breakdown of the microbe's structural integrity.	$18.70 per drape [8]	Limiting microbial growth at the surgical site, and reabsorbs wound exudate.	Skin irritation to the adhesive, sensitivity, iodine toxicity, or allergic reactions.
Silver	Silver damages cellular organelles vital for DNA and RNA synthesis, as well as cell wall formation. Silver also disrupts the functions of the mitochondria and enzymes needed for metabolism.	$38.05-40 per dressing [3,7]	Significant reduction in microbial growth at the surgical site, reduced number of dressing changes, reduced blister formation, and exudate reabsorption.	Skin irritation to the adhesive, sensitivity, contact dermatitis, or allergic reactions.

Discussion

With the development of antimicrobial-impregnated dressings (AMIDs), several studies have been conducted to assess the efficacy of the dressings in comparison to standard dressings for periprosthetic joint infections (PJIs) of total knee arthroplasty (TKA) and total hip arthroplasty (THA). Early investigations assessed the efficacy of iodine-impregnated dressings show mixed results [8,30]. Initial research on cadaver skin revealed iodine dressings have statistically significant antimicrobial activity against low and high inoculations of Methicillin-resistant Staphylococcus aureus (MRSA) in comparison to non-antimicrobial drapes, $P < 0.010$ [30]. Another early investigation assessed bacterial recolonization following the use of iodine drapes in a simulated TKA [31]. The study supported the use of iodine-impregnated dressings as the optimal choice for reducing infection rates compared to other dressing options. However, a retrospective study assessing the effectiveness of iodine dressings in total joint arthroplasty (TJA) suggested no significant difference in periprosthetic joint infection (PJI) rates when compared to non-antimicrobial drapes [8]. The study followed a cohort of 9,774 patients who received a TJA surgery between 2000 - 2012 [8]. They found PJI rates of 1.14% with iodine-drapes and 1.26% with standard dressings [8]. Additional research is necessary to assess the true effectiveness of iodine dressings on reducing PJI rates outside of cadaver and laboratory studies.

In recent years, research studies on silver-impregnated drapes has increased. When assessing effectiveness, Grosso et al. found that silver dressings yielded a four-fold reduction in PJIs when compared to standard dressings with statistical significance ($P = 0.03$) [7]. They approximate a national reduction of PJIs by 10,000 annual cases in the US with the implementation of silver dressings used for TJAs [7]. Other studies have reported similar findings with silver-impregnated dressings having significantly decreased PJI rates compared to standard dressings [28,32]. In addition to the reduction of PJIs, these studies also commented on the superior impact of silver drapes on wound healing [28,32]. The antimicrobial-impregnated products were shown to decrease rates of superficial surgical site infections (SSI), which is a known risk factor for PJIs [28,32]. When compared to standard products, the silver dressings were reported to have longer wear time and fewer dressing changes needed. One study revealed improved patient satisfaction scores with the visual analog scale (VAS) for pain, ease of use, and dressing removal [33]. Overall, silver-impregnated products have been shown to reduce both deep and superficial infection rates, and require fewer dressing changes in comparison to standard products.

The incidence of adverse effects when using AMIDs is minimally addressed in the literature. Of the recent studies that disclosed this information, the pertinent side effects were in patients with iodine and silver allergies or sensitivities [3,8,33]. The small patient population that had known allergies or exhibited signs of contact dermatitis were switched to standard dressings without complications [3,8,33]. Other side effects included local skin irritation in patients sensitive to adhesive materials.

With the significant reduction in PJI rates attributable to silver-impregnated dressing use, several researchers have inquired about whether it is cost effective to implement antimicrobial drape use and dressings for all TJAs. The average cost of silver-impregnated dressings ranges between $38.05 - $40 depending on product brand and facility contracts. The average cost to treat a PJI can range from $25,000 to $100,000 depending on the treating facility, insurance coverage, and severity of infection. One institution found an absolute risk reduction (ARR) of 0.40% with a number needed to treat (NNT) equal to 263 for infection treatments of low cost [3]. Another study determined an ARR of 0.16% and 0.13% for TKA and THA, respectively [34].

Over one million combined TKAs and THAs are performed annually [1]. Current expenditure on PJIs is estimated to be $500 million [28]. The estimated use of silver-impregnated dressings in all TJAs would cost $27 million annually [28]. Nationwide use of silver dressings could reduce the total national expenditure on the treatment of PJIs from $500 million to $125 million [28]. These estimates result in a net savings of $348 million for the treatment of PJIs [28]. The evidence highlights that while AMIDs may have higher upfront costs compared to standard dressings, their benefit in risk reduction of PJIs can be argued as cost efficient.

Study Limitations and Future Perspectives

Silver antimicrobial-impregnated dressings (AMIDs) are commonly used in infection prevention after total joint arthroplasty (TJA), so this review is limited in scope of more novel AMIDs for the reduction of periprosthetic joint infections (PJIs) or primary TJA of the hip and knee. There remain limitations in understanding the number needed to treat (NNT) for AMIDs, but a recent study demonstrates an NNT of 263 for using silver-based AMIDs in TJA [3]. Iodine AMIDs and drapes could be a viable and cost-effective option for helping reduce the risk of TJA in the future, but the NNT is also not clear for TJA of the hip and knee. Iodine AMIDs have a lower cost per dressing change and a lower cytotoxic risk than silver AMIDs [24]. Although iodine AMIDs have conventionally been used for wound control, more research should be completed to determine their efficacy in the prevention of PJIs. In an effort to lower healthcare costs without compromising patient care, iodine AMIDs could be an adjunctive solution for TJA infection mitigation. Future research should explore the integration of advanced technologies in antimicrobial dressing, such as silver nanoparticles and controlled-release systems, to enhance antimicrobial activity, and promote effective wound healing [35,36]. There is emerging evidence that suggests that nanotechnology-based wound dressings can achieve antimicrobial effects, while reducing the risk of contamination [37]. Further research in personalized wound care approaches should be conducted. Risk factors, such as comorbidities, nutritional status, and prior infection history should be considered. Prior studies have demonstrated risk factors for PJIs, such as poorly-controlled diabetes mellitus, liver disease, chronic kidney disease, and immunosuppression. However, it is unclear in the current literature if patients with higher risk factors for PJIs with primary TJA of the hip and knee have clinically reduced rates of PJIs with use of AMIDs postoperatively. Large-scale, multicenter randomized controlled trials are needed to validate efficacy across diverse populations for AMIDs. Continued innovation in dressing technology holds promise for reducing PJIs and improving the standard of postoperative care in joint arthroplasty.

Conclusion

Periprosthetic joint infections (PJIs) remain one of the most challenging and costly complications following total joint arthroplasty (TJA). Despite the relatively low incidence of PJIs, their consequences on patient morbidity, patient-reported outcomes, and healthcare costs are profound. Antimicrobial-impregnated dressings (AMIDs), particularly those containing silver, have emerged as an adjunctive modality to help reduce the risk of wound complications and PJIs. Multiple studies demonstrate the utility and cost-effectiveness of AMIDs in reducing risk of PJIs. Silver-impregnated showed significant results in reducing the risk of PJIs when compared to standard dressings. One study estimated that using AMIDs, particularly with silver, could reduce the nationwide cost of PJIs from $500 million to $125 million, but further research is necessary to assess the number needed to treat (NNT). Iodine-impregnated drapes had mixed results when compared with standard drapes. Silver-impregnated dressings were more expensive than iodine ($38.05-40 versus $18.70 on average), but there is variability in costs and product availability depending on facility contracts among other factors. More research is needed to investigate silver and iodine AMIDs, the appropriate patient populations to utilize AMIDs in, and if it is cost effective for routine use in primary TJA of the hip and knee. This review highlights the growing evidence supporting the use of AMIDs in TJA procedures with their relatively low cost and ease of use. While early results are encouraging, further research is essential to investigate the utilization of AMIDs in TJA of the hip and knee for reducing PJIs.

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