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The Role of Negative Pressure Wound Therapy in Temporizing Traumatic Wounds before Lower Limb Soft Tissue Reconstruction: A Systematic Review

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Background: In practice, there is often a delay from initial debridement and temporary fixation to definitive soft tissue coverage of traumatic leg wounds. Without clear evidence, conservative negative pressure wound therapy (NPWT) is increasingly used to temporize these wounds. This systematic review summarizes and synthesizes the literature on using NPWT to temporize traumatic leg wounds before surgery in adult surgical patients.
Methods: A comprehensive search of Medline, Embase, and Cochrane Library was performed from inception until July 2022, inclusively. Two independent reviewers performed screening, data extraction, and risk of bias assessment. Primary English studies, including adult patients (≥16 years old) with a fracture below the knee up to and including the ankle that received NPWT to temporize wounds before definitive soft tissue reconstruction with a flap and/or graft, were included.
Results: Thirty-four studies, including 804 patients who received NPWT, were included. The partial/total flap loss rate was 6.95% (n = 9 studies), the infection rate was 19.5% (n = 25 studies), the nonunion rate was 18% (n = 15 studies), the delayed union rate was 9.31% (n = 3 studies), and the amputation rate was 15.4% (n = 6 studies). The mean late stay was 43.1 days (n = 9 studies), and the follow-up length was 23.7 months (n = 9 studies). The mean time to wound healing was 5.63 months (n = 2 studies), and the time to soft tissue coverage was 40.8 days (n = 12 studies). The mean time to achieve bone union was 7.26 months (n = 6 studies).
Conclusion: NPWT can be used to temporize traumatic wounds while awaiting soft tissue reconstruction. *(Plast Reconstr Surg Glob Open 2024; 12:e6003; doi: 10.1097/GOX.0000000000006003; Published online 26 July 2024.)*

INTRODUCTION

Lower extremity trauma is associated with extensive patient morbidity, as there is an increased incidence of infection, nonunion, and wound necrosis, which can delay wound healing and result in amputation.[1]

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Although immediate reconstruction may be considered the gold standard at present, we have shown that in surgical practice, when a patient presents with significant lower extremity trauma (ie, fracture with overlying skin deficits), there is a delay from initial debridement and temporary fixation to definitive management with soft tissue coverage.[2] This delay may be due to concomitant injuries, the patient's clinical status, or resource availability, among other reasons. Negative pressure wound therapy (NPWT), a noninvasive wound healing adjunct, has previously been extensively used to manage chronic and acute wounds.[3] The use of NPWT in these different clinical contexts has been suggested to expedite wound healing, reduce complications, and circumvent the need for soft tissue coverage.[3] More recently, it has become an attractive option to temporize traumatic wounds while awaiting

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definitive soft tissue coverage with flaps and grafts. For example, Godina showed that performing reconstruction with flaps within the first 72 hours from the time of trauma reduces the length of hospital stay, increases flap survival, and reduces the rate of infection.[4] In this seminal study, 532 patients underwent microsurgical reconstruction either within 72 hours, between 72 hours and 3 months, or between 3 months and three years following trauma to the lower extremities.[4] He found reduced flap failure rates (0.75%), postoperative infections (1.5%), bone healing time (6.8 months), and the average length of hospital stay was 27 days.[4] On average, patients managed acutely also underwent fewer operations (average of 1.3 operations).[4]

Several groups have investigated the role of temporizing lower extremity traumatic wounds with NPWT; however, no consensus exists on its effect. This systematic review aimed to provide an overview and synthesis of the available literature on the use of NPWT in temporizing traumatic wounds in adult patients awaiting definitive soft tissue coverage for the lower limb.

Takeaways

Question: What is the role of NPWT in temporizing traumatic leg wounds before definitive surgery in adult surgical patients based on the available literature?

Findings: Our systematic review suggests that NPWT can be used to temporize traumatic wounds while awaiting definitive soft tissue coverage within worsening postoperative outcomes.

Meaning: NPWT can be used to temporize traumatic wounds while awaiting soft tissue reconstruction.

METHODS

Before conducting this review, a protocol was registered on Open Science Framework (https://osf.io/k36jq). This study was performed per the performed reporting items for systematic reviews and meta-analyses guidelines.[5]

Search Strategy

A comprehensive search of Medline (via Ovid), Embase (via Ovid), and the Cochrane Library (via Wiley) was performed from inception until July 2022, inclusively. The primary search strategy was developed on Medline. The vocabulary and syntax of the Medline strategy were tailored and adapted to the other databases. No restrictions were placed on the study's year or publication status. Language (English only) and human participant study restrictions were applied in Medline and Embase only. Keywords and index/subject terms were joined by Boolean operators "AND" or "OR." The search strategy can be found in Supplemental Digital Content 1. (**See table, Supplemental Digital Content 1,** which displays search strategies, **http://links.lww.com/PRSGO/D362**.) Retrieved citations were uploaded into an EndNote library for deduplication.

Study Selection and Data Extraction

Following deduplication, the endnote library was uploaded into Rayyan (Rayyan Systems Inc., Cambridge, Mass.), an online systematic review software. Title and abstract screening were performed by two independent reviewers (N.B., N.Z.) against prespecified eligibility criteria. Included studies comprised of any randomized controlled trials (RCTs), prospective studies, retrospective studies, case-control studies, case series, letters to the editor and case reports containing adult patients (≥16 years old) who received NPWT to temporize a traumatic wound (with an underlying fracture) while awaiting definitive lower limb surgery (ie, definitive soft tissue reconstruction with grafts or flaps). Pertinent reviews (systematic reviews and meta-analyses, literature reviews, narrative reviews, etc.) were solely retained so that the reference lists could be cross-referenced to identify any additional articles not captured by the search. The lower limb was defined as any region below the knee, including the ankle. Abstracts (conference or other) and protocols not traced to full text and commentaries were excluded. Retained studies underwent full-text assessment, for which eligible studies underwent data extraction. Any disagreements regarding study eligibility were resolved through consensus and, when necessary, through discussion with a third reviewer (S.H.). Data extraction was performed using a piloted form that was created in Excel. Data points extracted are available in Supplemental Digital Content 2. (**See table, Supplemental Digital Content 2,** which displays data points extracted from each primary study, **http://links.lww.com/PRSGO/D363**.)

Data Synthesis

The initial aim of this study was to perform a meta-analysis; however, given the significant heterogeneity in outcome reporting, lack of controls, and inconsistency in the types of controls used, this was deemed not possible. Data were therefore summarized descriptively in the text and using study tables. Where applicable, descriptive statistics were used to calculate overall means and percentages (eg, age, follow-up, infection rate). Again, no statistical comparisons were performed, given the lack of control groups.

Risk of Bias Assessment

The Joanna Briggs risk of bias tool was used to assess the methodological quality of included studies. Specifically, the risk of bias tools for RCTs, case-control studies, cohort studies, case series, and case reports were used. Two reviewers independently performed the risk of bias assessment, and disagreements were resolved through consensus and, when necessary, through discussion with a third reviewer (S.H.).

RESULTS

Search Outcome

Through the database search, 5329 studies were identified, of which 876 studies were duplicates. A total of 4453

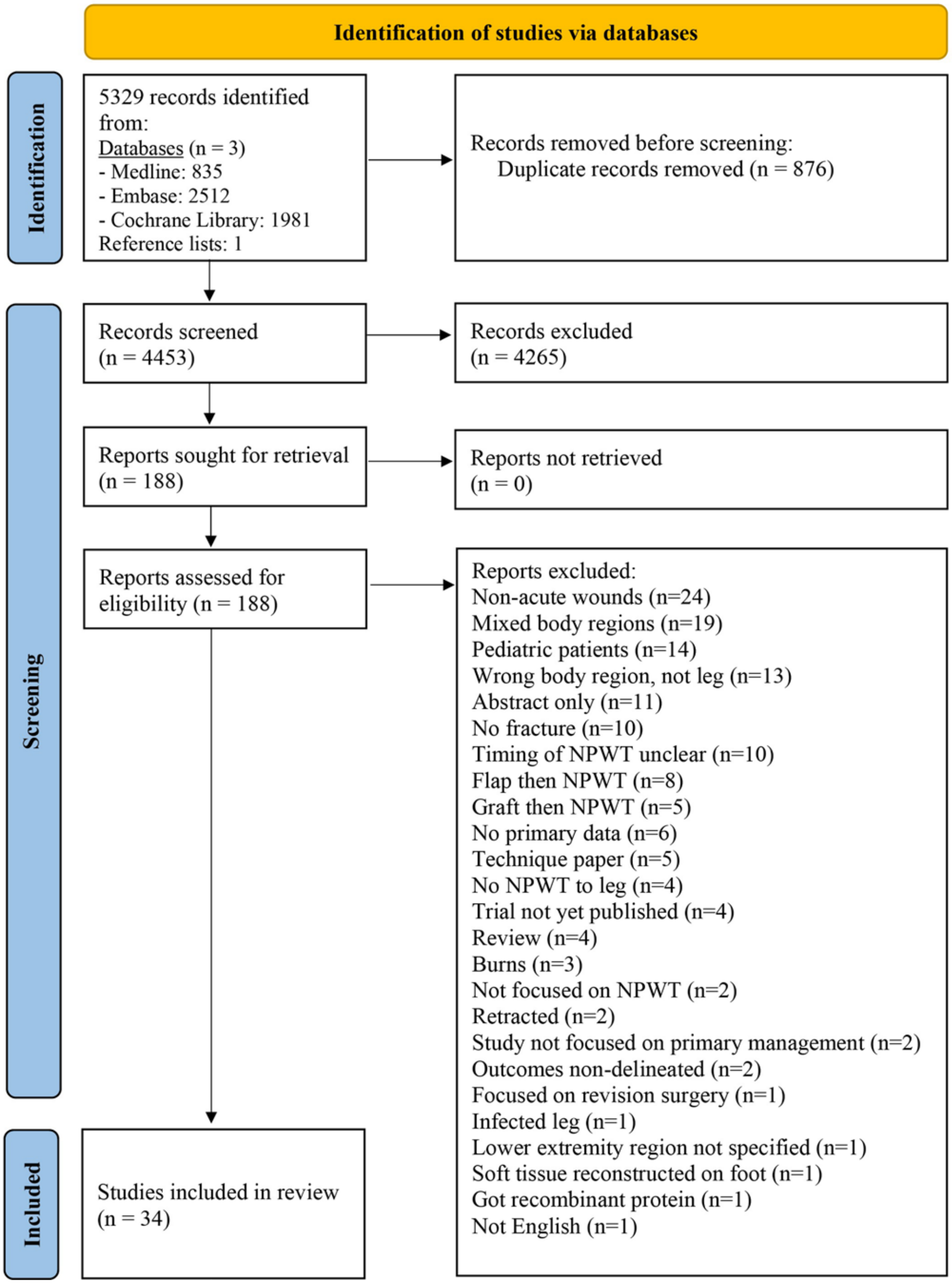

Fig. 1. Performed reporting items for systematic reviews and meta-analysis diagram.

studies underwent title and abstract screening, of which 188 were eligible for full-text assessment based on the strict inclusion criteria outlined above. Thirty-four studies were included.[6–39] The remaining 154 studies were excluded at the full-text stage for the following reasons (Fig. 1): non-acute wounds (n = 24 articles); mixed body regions (n = 19 articles); pediatric patients (n = 14); wrong body region, not leg (n = 13); abstract only (n = 11); no fracture (n = 10); timing of NPWT unclear (n = 10); flap then NPWT (n = 8); graft then NPWT (n = 5); no primary data (n = 6); technique article (n = 5); no NPWT to leg (n = 4); trial not yet published (n = 4); review (n = 4); burns (n = 3); not focused on NPWT (n = 2); retracted (n = 2); study not focused on primary management (n = 2); outcomes nondelineated (n = 2); focused on revision surgery (n = 1); infected leg (n = 1); lower extremity region not specified (n = 1); soft tissue reconstructed on foot (n = 1); got recombinant protein (n = 1); and not English (n = 1). Reasons for excluding individual studies are provided in Supplemental Digital Content 3. (**See table, Supplemental Digital Content 3,** which displays a table of exclusions, **http://links.lww.com/PRSGO/D364**.)

Risk of Bias

Risk of bias assessment was performed on all eligible studies (n = 31 studies)[6–36]: 13 case series,[6–17,36] 11 case reports,[23–33] four cohort studies,[18–21] two case controls,[34,35] and one RCT.[22] The risk of bias for the individual studies is reported in Supplemental Digital Content 4. (**See tables, Supplemental Digital Content 4**, which displays Joanna Briggs risk of bias of included studies, **http://links.lww.com/PRSGO/D365**.)

Study Characteristics

Among the 34 studies included, 13 were case series,[6–17,36] 11 were case reports,[23–33] four were cohort studies,[18–21] two were case controls,[34,35] two were letters to the editor,[37,38] one was an RCT,[22] and one was a correspondence and communication.[39] Studies were predominantly performed in the USA (n = 11 studies),[7,9,10,20,21,24,29–31,37,39] followed by China (n = 6 studies),[6,13,15,26,35,36] Australia (n = 2 studies),[11,18] India (n = 2 studies),[12,22] Japan (n = 2 studies),[17,38] Singapore (n = 2 studies),[16,19] Switzerland (n = 2 studies),[32,34] Turkey (n = 2 studies),[23,33] Korea (n = 2 studies),[14,28] England (n = 1 study),[27] Italy (n = 1 study),[8] and Argentina (n = 1 study).[25] Eleven (32.4%) studies reported on their funding status,[6,15,16,24–26,28,32,35,37,38] of which three reported having received no funding,[16,26,28] and eight reported having received funding.[6,15,24,25,32,35,37,38] Data from individual studies are available in Supplemental Digital Content 5. (**See table, Supplemental Digital Content 5,** which displays characteristics of included studies, **http://links.lww.com/PRSGO/D366**.)

Patient Characteristics and Study Group Details

Patient demographics and study group details are presented in Supplemental Digital Content 6. (**See table, Supplemental Digital Content 6,** which displays the characteristics of included participants, **http://links.lww.com/PRSGO/D367**.) A total of 1051 patients were included in this review; 804 patients received NPWT, and 247 patients received a control dressing to temporize their wounds before soft tissue reconstruction. All patients were aged 16 years and older and had fractures below the knee up to or including the ankle. Twenty-six studies[6–9,11–16,18,20,21,23,24,27–34,36,37,39] reported on the etiology of the trauma, which predominantly included motor vehicle accidents (car or motorcycle, n = 17 studies),[6,7,9,11,12,14–16,18,20,21,24,29,32,34,36,39] falls (n = 14 studies),[6,7,9,12,14,15,18,20,21,27,31,34,36,37] gunshot injuries (n = 6 studies),[9,13,21,23,30,33] pedestrians struck by a car (n = 3 studies),[7,14,18] and crush injuries (n = 7 studies).[6,9,15,21,24,28,34]

The details regarding the management performed before definitive soft tissue reconstruction for each of the included studies are available in Supplemental Digital Content 7. (**See table, Supplemental Digital Content 7,** which displays the intervention characteristics, **http://links.lww.com/PRSGO/D368**.)

Among those who used a form of NPWT, one study used vacuum sealing drainage.[36] Seven studies contained a control group as a comparator,[18–22,34,35] including conventional dressings, occlusive dressings, wet-to-dry dressings, and Epigard. Definitive reconstruction was performed with only a flap, only a graft, or a combination of flaps and grafts, as described in Supplemental Digital Content 7.

Table 1. Outcomes

Outcome	No. Studies	Result
Overall mean length of stay	9	43.1 (range: 20–77) days
Overall mean follow-up length	9	23.7 (range: 5.7–59.4) months
Overall mean time to wound healing	2	5.63 (range: 3.5–7.76) months
Overall mean time to soft tissue coverage	12	40.8 (range: 6.85–248) days
Overall mean time to achieve bone union	6	7.26 (range: 5.25–8.47) months
Overall mean number of revisions/reoperations	8	8.4
Partial and/or total flap loss rate	9	6.95% (29/417 patients)
Infection rate	25	19.5% (154/790 patients)
Nonunion rate	15	18% (110/610 patients)
Delayed union rate	3	9.31% (19/204 patients)
Amputation rate	6	15.4% (41/267 patients)

Outcomes

All outcomes were reported in Table 1 and Supplemental Digital Contents 7 and 8. (**See table, Supplemental Digital Content 7,** which displays intervention characteristics, **http://links.lww.com/PRSGO/D368**.) (**See table, Supplemental Digital Content 8,** which displays outcomes, **http://links.lww.com/PRSGO/D369**.) All results are reported for patients with wounds temporized with NPWT before definitive soft tissue reconstruction. Of note, although NPWT was used before definitive management, there were occurrences where final soft tissue coverage was not necessary; however, given that the numbers were not documented, analysis could not be performed. In nine studies,[6,13,18,20,21,26,27,34,38] the mean length of stay was reported. The overall mean length of stay was 43.1 days (mean range 20–77 days). Among the nine studies[6,12–15,20,22,29,36] reporting mean follow-up, the overall mean follow-up length was 23.7 months (mean range 5.75–59.4 months). Only two studies reported the time to wound healing,[6,39] of which the overall mean time to wound healing was 5.63 months (mean range 3.5–7.76 months). Twelve studies[7,9,13,14,17,19,22,24,26,29,30,39] reported the time to soft tissue coverage. The overall mean time to soft tissue coverage was 40.8 days (mean range 6.85–248 days). Nine studies[9,10,13,14,18–21,36] reported partial and/or total flap loss, of which the flap loss rate was 6.95% (29 of 417 patients). The occurrence of infection was reported in 25 studies.[6–10,12–22,26,27,30–32,34–36,39] The rate of infection was 19.5% (154 of 790 patients). Among the six studies that reported the time to achieve bone union,[6,12–14,21,36] the overall mean time required was 7.26 months (mean range 5.25–8.47 months). Cases of nonunion were reported in 15 studies[9,10,12–16,18,20,21,25,32,34–36] resulting in a nonunion rate of 18% (110 of 610 patients). In comparison, three studies reported delayed union[14,18,36] for an overall delayed union rate of 9.31% (19 of 204 patients). Six studies[9,10,13,21,34,35] reported the number of patients undergoing amputation, of which the overall amputation rate was 15.4% (41 of 267 patients). Seven studies[14,16,24–26,28,29] reported on the ability to ambulate; all patients could ambulate with or without a walker postoperatively. Twelve studies[9,10,12,14–18,20,21,27,32] reported the need for revision/reoperation; however, only eight[10,12,14,16,18,20,21,27] provided data on the number of revisions or reoperations performed. The mean number of revisions/reoperations performed was 8.4.

Pain scores, patient satisfaction, and quality of life were either scantly reported or not reported by any of the included studies. Therefore, they are not discussed here.

DISCUSSION

Practically speaking, whether it be due to concomitant injuries, the patient's clinical status, or the availability of resources, it is often impractical to perform soft-tissue coverage (whether flap or graft) acutely following presentation to a health care center. Godina's seminal work provided evidence to support that performing early reconstruction results in significantly lower rates of free-flap failure, infection rates, and the number of additional procedures but no difference in bone healing time or length of stay.[2] Over the last several decades, there have been advances in medical technology that could potentially improve outcomes if used before definitive coverage. Thus, studying modalities that can be used in the interim to temporize traumatic wounds is critical.

NPWT is increasingly used to temporize traumatic injuries; however, the literature on its use remains limited. Only one systematic review performed by Qiu et al provided a brief comment that five studies (including 182 patients, 193 flaps), had discussed using NPWT to temporize traumatic wounds to any bodily region, of which only one study included a control group.[40] Given the frequent use of NPWT in clinical practice and the lack of consensus on the value of its use, we performed a systematic review to assess the use of NPWT as a modality to temporize traumatic wounds while awaiting definitive soft tissue coverage.

Here, we report complication rates in patients undergoing NPWT before definitive management of the lower extremity, specifically below the knee up to and including the ankle. When patients were treated with NPWT, the infection rate was 19.5%, the nonunion rate was 18%, the amputation rate was 15.4%, the partial/total flap rate was 6.95%, the time to achieve bone union was 7.26 months, and the length of stay was 43.1 days. A recent systematic review and meta-analysis by Nicolaides et al identified a 14.3% infection rate and 14.2% nonunion rate among their cohort of tibial fractures ranging from Gustilo Anderson type I to III.[41] In a systematic review by Schade et al, which assessed outcomes of patients with open tibia fractures in low- and middle-income countries, they reported an 18% infection rate, 15% nonunion rate, 15% amputation rate, and a mean follow-up of 19.8 months.[42] Of note, neither of these articles used NPWT. In Godina's study, he reported a flap failure rate of 12%, a postoperative infection rate of 17.5%, a bone healing time of 12.3 months, a mean length of hospital stay of 130 days, and an average of 4.1 performed in the delayed reconstruction group.[4] We want to highlight a few studies included in this review. Dedmond et al[10] found that infection and nonunion rates when NPWT is used for temporary coverage were similar to historical controls, and concluded that flaps might not be required. Hou et al[13] proposed that NPWT can help reduce flap sizes and need for flap transfer; however, if used for longer than 7 days, it could lead to infection and amputation risks. Blum et al[18] found that NPWT reduced the rate of deep infection for open tibial fractures compared with conventional dressings. Joethy et al[19] found that patients receiving NPWT had lower infection rates and flap failure compared with a cohort that had occlusive dressings. Lastly, according to Virani et al,[22] NPWT was beneficial in preventing the incidence of both acute infections and osteomyelitis compared with patients who got periodic irrigation, cleaning and debridement. They did not see a significant difference in the time required for the wound to be ready for delayed primary closure or coverage. In summary, the results we report here align with the findings available in the literature however, most studies focused on patients reconstructed with flaps. Therefore, this suggests that NPWT can be used to temporize traumatic wounds while awaiting definitive soft tissue coverage within worsening postoperative outcomes. Given that NPWT serves as a barrier, stimulates granulation tissue, and helps prevent fluid collection, it can help provide a temporary treatment option to maintain a region that will eventually be amenable to soft tissue reconstruction. However, we must acknowledge the disadvantages of using NPWT, which include pressure necrosis, availability, need for electricity, and the cost of the machine, which could be a barrier to access in lower-income countries.[43]

There are limitations to our study. We attempted to include all studies where NPWT was used, even if the objective of those studies was not explicitly aimed at assessing the role of NPWT. This led to having mixed cohorts, which did not stratify results. There were also inconsistencies in reporting patient and treatment characteristics and outcomes, which limited the analyses performed. For example, partial and complete flap loss was pooled, as several studies failed to specify these details. Moreover, data was not stratified by flap and graft but rather provided as averages for soft tissue reconstruction. Few comparative studies and RCTs were available, limiting the comparison of NPWT to other management options. Among the studies that did have control groups, the control dressings were different therefore the data could not be aggregated. Given these limitations and the significant heterogeneity, a meta-analysis was not performed.

Given the limited access to immediate reconstruction in practice, we must find solutions to temporize traumatic wounds. The role of NPWT is a very active area of research in the surgical field, but the current data lacks critical information on its use and associated outcomes. Therefore, here we present recommendations for future studies. First, future studies should prioritize prospective cohorts, ideally blinded RCTs with large patient cohorts. Second, the data should be stratified based on the region where fractures occurred. Third, reporting adequate patient demographics, including age, sex, body mass index, and comorbidities, is critical to understand the patient's baseline medical status. As well, they should also report how often the dressing was changed. The final status of the wound before definitive soft tissue coverage and the postoperative outcomes (eg, surgical site infections, wound dehiscence, flap failure, bone healing, ambulation, amputation) should also be noted.

CONCLUSIONS

The current consensus concerning the management of lower extremity injuries is that patients should be taken to the operating theater acutely for soft tissue reconstruction. However, given the numerous resources needed to mobilize such an effort (eg, availability of operating theater, surgeon schedule, operating room, postanesthesia care unit personal availability, surgical beds) and the patient's overall status/wound being ready, it is often difficult to do so. There is also no concrete evidence to show that temporizing wounds before definitive surgery improves outcomes. We provide initial evidence to support that NPWT can be used to temporize wounds awaiting definitive soft tissue reconstruction. However, more robust RCTs with large cohorts focused explicitly on the role of NPWT are necessary to obtain a comprehensive understanding of the risks and benefits.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

ETHICS APPROVAL

No ethics approval was required for the performance of this review.

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