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GENERAL REVIEW

Negative pressure wound therapy in the management of postoperative spinal wound infections: a systematic review

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Abstract

Introduction Postoperative wound infection after spinal surgery might be a challenge to manage. A wide range of procedures have been described for managing infected spinal wounds. An increasingly common procedure in the management of surgical site infections (SSI) is negative pressure wound therapy (NPWT), also known as vacuum-assisted closure. As there is a paucity of clear clinical advice the present investigation aims to update current evidence on the use of NPWT to manage postoperative SSI occurring after instrumented spine surgery.

Methods This systematic review was conducted according to the preferred reporting Items for systematic reviews and meta-analyses: the 2020 PRISMA statement. In January 2024, the following databases were accessed: PubMed, Web of Science, and Google Scholar. No time constraint was set for the search. All the clinical studies investigating the unique use of NPWT in treating postoperative spinal wound infections were accessed.

Results A total of 381 patients were included in the present study. Of them 52.5% (200 of 381 patients) were women. The mean age was 52.2 ± 15.2 years. The average length of the NPWT was 21.2 days (range 7–90 days).

Conclusion NPWT could be a valuable adjuvant therapy for the management of SSI after spine surgery. Additional high-quality investigations are required to assess the efficacy and safety of NPWT in SSI after spine surgery, especially if combined with contraindications or risk factors, such as the presence of intraoperative CSF leak.

Level of evidence Level IV, Systematic review

Keywords Spine · Infection · SSI · Negative pressure wound therapy

Introduction

Postoperative wound infection after spinal surgery, especially after instrumentation, represents a serious problem and a challenge for physicians [1–3]. Delayed wound healing leads to morbidity, pain, and discomfort and requires prolonged treatment and hospitalisation as well as major reconstructive surgery, which causes enormous social and financial costs [4, 5]. The reported incidence of surgical site infections (SSI) after spinal surgery ranges from 0.4 to 20% and increases with the complexity of the procedure [6, 7]. Standard interventions to reduce the risk of wound complications include pre-operative prophylactic antibiotics, drain placement, copious lavage, and careful wound closure

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[8–11]. An early and precise diagnosis of delayed wound healing after spinal surgery is the key to preventing superficial infections from becoming deep infections [12].

A wide range of procedures have been described for managing infected spinal wounds [13–15]. Some authors documented one-procedure techniques by re-opening the wound, debridement, primary closure and antibiotic treatment [16–18]. Another option is the irrigation suction with delayed primary closure of the wound [19–23]. If the defect space is too broad to close primarily or delayed, muscle flaps are required to provide a soft tissue closure [24–27]. Another increasingly common procedure in the management of SSI after spinal surgery is negative pressure wound therapy (NPWT), also known as vacuum-assisted closure (VAC; Kinetic Concepts Inc., San Antonio, TX, USA). This device is a white foam containing a tubing system that is placed bilaterally on the spine at the subfascial level. The fascia and the soft tissues are being closed and the foam is connected to the vacuum pump (Fig. 1).

First proposed by Morykwas et al. [28] in 1997 it has been routinely implemented in the treatment of wounds with delayed healing on the extremities, open wounds following severe trauma, open sternal and abdominal wounds, and pressure ulcers in recent years [29–36]. As there is a paucity of clear clinical advice the present investigation aims to update current evidence on the use of NPWT to manage postoperative SSI occurring after instrumented spine surgery.

Methods

Eligibility criteria

All the clinical studies investigating the unique use of NPWT in treating postoperative spinal wound infections were accessed. According to the author's language capabilities, articles in English, German, Italian, and Spanish were eligible. Only studies with level I–IV of evidence, according to the Oxford Centre of Evidence-Based Medicine [37], were considered. Studies published in grey literature or without full-text were not eligible. Opinions, letters, and editorials were not considered. Animals, in vitro, biomechanics, computational, and cadaveric studies were not eligible. Missing quantitative data under the outcomes of interests warranted the exclusion of the study.

Search strategy

This systematic review was conducted according to the preferred reporting items for systematic reviews and meta-analyses: the 2020 PRISMA statement [38]. The following framework was used to guide the literature search:

- Problem: SSI following spinal surgery;
- Intervention: NPWT;
- Outcomes: time wound healing, contraindications and complications using vacuum-therapy

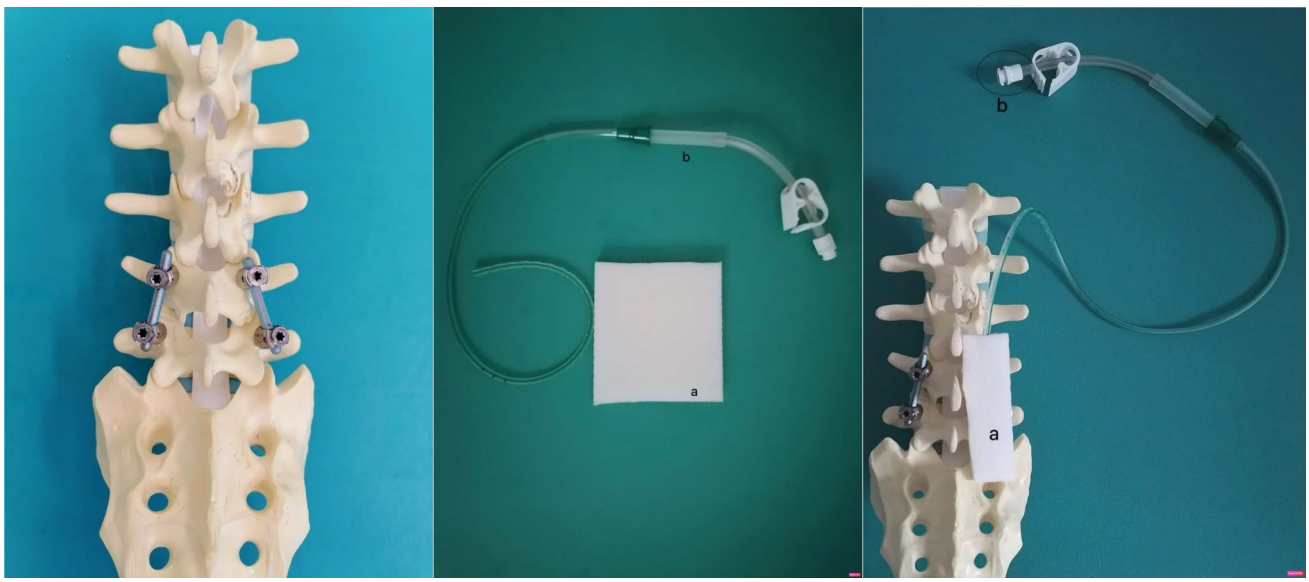


Fig. 1 Left: saw-bone model of lumbosacral spine with instrumentation at L4-5; centre: **a** white foam and **b** tubing; right: **a** white foam with the tubing is put on the hardware **b** connector for the vacuum pump

In January 2024, the following databases were accessed: PubMed, Web of Science, and Google Scholar. No time constraint was set for the search. The following matrix of keywords was used in each database to accomplish the search using the Boolean operator AND/OR: wound OR infected wound AND VAC OR vacuum-assisted closure OR NPWT OR negative pressure wound therapy ADN scoliosis AND spinal surgery OR spine surgery. No additional filters were used in the database search.

Selection and data collection

Two authors (LS and GP) independently performed the database search. All the resulting titles were screened by hand and, if suitable, the abstract was accessed. The full-text of the abstracts, which matched the topic was accessed. If the full-text was not accessible or available, the article was not considered for inclusion. A cross reference of the bibliography of the full-text articles was also performed for inclusion. Disagreements were debated and mutually solved by the authors. In case of further disputes, a third senior author (FM) decided.

Data items

Two authors (LS and GP) independently performed data extraction. The following data at baseline were extracted: author, year and journal of publication, study design, and patient characteristics, including mean age, number of women, the time when patients developed the first signs and symptoms of wound infections, and main findings including the type of surgical procedure, symptoms, diagnosis, treatment and complications. Data were extracted in Microsoft Office Excel version 16.72 (Microsoft Corporation, Redmond, USA).

Assessment of the risk of bias

The risk of bias was evaluated according to the guidelines in the Cochrane Handbook for Systematic Reviews of Interventions [39]. Given the diverse variety of article types, The risk of bias in non-randomised studies of interventions (ROBINS-I) tool was used for all included non-randomised controlled trials (non-RCTs) [40]. Seventeen domains of potential bias in non-RCTs were assessed. Possible confounding and the nature of patient selection before the start of the comparative intervention are assessed by two domains. A further domain is used to assess bias in the classification during the intervention. The final four domains assess the methodological quality after the intervention comparison has been implemented and relate to deviations from previously intended interventions, missing data, erroneous measurement of outcomes, and bias in the selection of reported outcomes. The figure of the ROBINS-I was elaborated using the Robvis Software (Risk-of-bias VISualization, Riskofbias.info, Bristol, UK) [41]. Case reports included in this investigation were evaluated by using the Joanna Briggs Institute (JBI) criteria appraisal tools for case reports [42]. Possible answers were "yes", "no", "unclear", or "not applicable". To evaluate the methodological quality, following the JBI checklist, eight questions were answered. Articles were evaluated based on the following criteria: low risk of bias: studies with more than six "yes"; moderate risk of bias: studies with five to six "yes"; and high risk of bias: studies with less than five "yes". Two reviewers (LS and GP) evaluated the risk of bias in the extracted studies independently. Disagreements were solved by a third senior author (FM).

Statistical analysis

For the statistical analyses, the IBM SPSS software version 25 was used. For representative statistics, the arithmetic mean and standard deviation is used.

Results

Study selection

The literature search resulted in 87 articles. Of them, 39 were excluded as they were duplicates. Additionally, 28 studies were excluded for the following reasons: study design ($N=1$), full-text not available or in peer-reviewed journals ($N=4$), not evaluating NPWT in the management of SSI following spinal surgery ($N=18$) and language limitations ($N=5$). An additional 18 studies were excluded, because they did not offer quantitative data on the outcomes of interest. Finally, 20 articles were included in the present investigation. Of them, 17 had a retrospective study design and two were case reports. The results of the literature search are shown in Fig. 2.

Methodological quality assessment

The ROBINS-I was applied to investigate the risk of bias in 85% (17 of 20) of the included studies, as they were non-RCTs. The assessments of the methodological quality are given in Fig. 3.

The risk of bias using the JBI criteria appraisal tool for case reports was evaluated in 10.6% (2 of 19) of the included studies, as they were case reports. The detailed assessment steps are shown in Fig. 4.

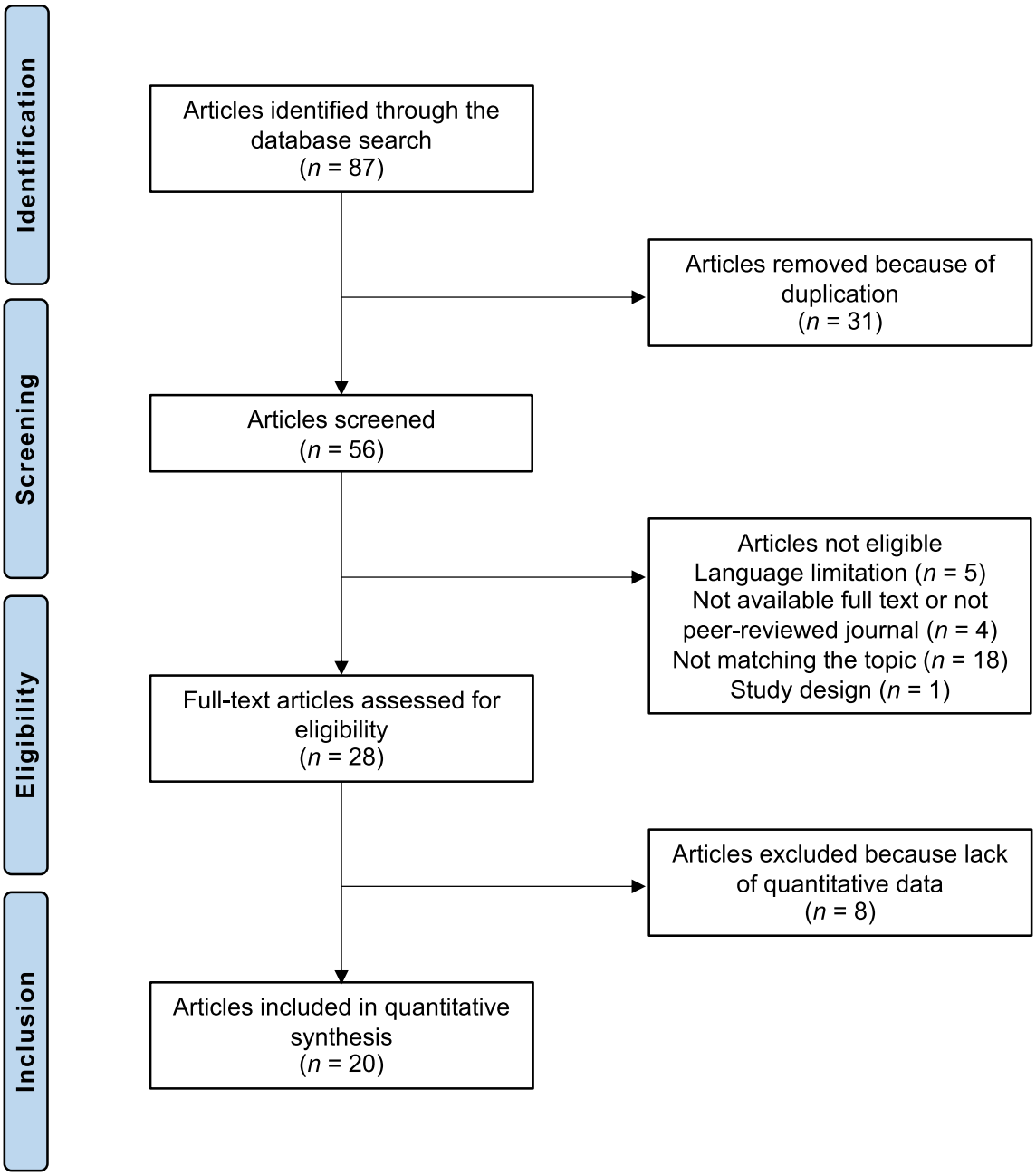


Fig. 2 PRISMA flow chart of the literature search

Study characteristics and results of individual studies

A total of 381 patients were included in the present study. Of them 52.49% (200 of 381 patients) were women. The mean age was 52.2 ± 15.2 years. The average length of the NPWT was 21.2 days, with wide variability (7–90 days). The generalities, patient characteristics and main findings of the included studies are shown in Table 1.

Discussion

Over the last decades, the number of spinal fusion surgeries has increased and so has the associated number of complications, including SSI [60, 61]. Current literature reports a highly variable incidence rate of SSI ranging from 0.6 to 3% for spinal lumbar microdiscectomy and decompression if compared with spinal instrumented fusion surgery, which shows an incidence of SSI from 6 to 18% [62, 63]. Many

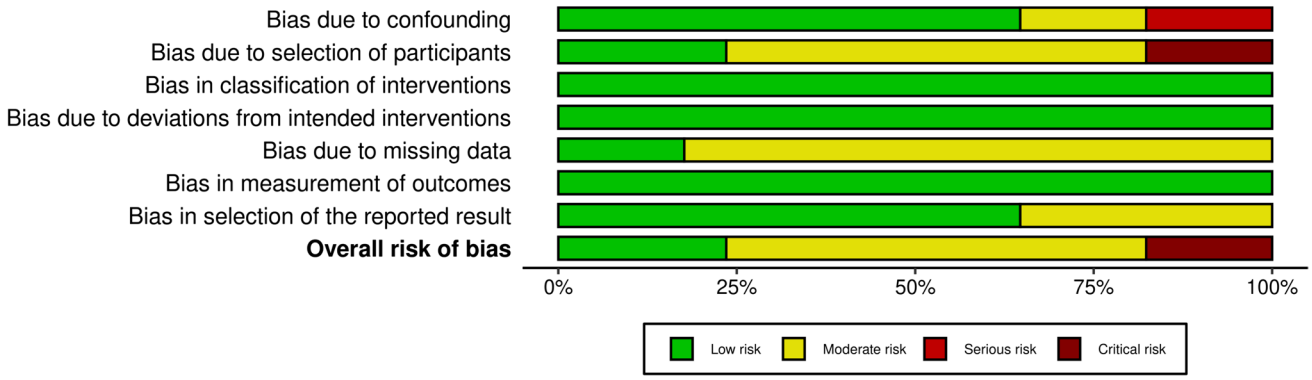


Fig. 3 The ROBINS-I of non-RCTs

Author, year	D1	D2	D3	D4	D5	D6	D7	D8	Overall
Patel et al., 2019	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Zhang et al., 2018	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Low

Domains:

D1: Were patient's demographic characteristics clearly described?
D2: Was the patient's history clearly described and presented as a timeline?
D3: Was the current clinical condition of the patient on presentation clearly described?
D4: Were diagnostic tests or assessment methods and the results clearly described?
D5: Was the intervention(s) or treatment procedure(s) clearly described?
D6: Was the post-intervention clinical condition clearly described?
D7: Were adverse events (harms) or unanticipated events identified and described?
D8: Does the case report provide takeaway lessons?

Fig. 4 JBI criteria appraisal tool for case reports

risk factors are known to increase the probability of SSI after instrumented spinal surgery [64–66]. A distinction is made between modifiable and non-modifiable risk factors. Modifiable risk factors include obesity (BMI ≥ 30), malnutrition, smoking, rheumatic diseases, cancer, prolonged hospitalisation, drugs, and alcohol abuse [67–71]. Non-modifiable risk factors are represented by immunosuppression, steroid therapy, advanced age, diabetes mellitus, and polytrauma, especially with spinal cord injury and neuromuscular scoliosis [72–74]. Children with neuromuscular scoliosis often present a reduced cardiopulmonary function and metabolic compromise already before surgery, which together with mental retardation, meningomyelocele, cerebral palsy and need for longer fusion are more prone to SSI [55, 75]. A further distinction is made into superficial infections, which are limited to the cutis and subcutis without involving the fascia layers, and deep infections, which extend below the fascia [76, 77]. If the infection occurs within three weeks of surgery it is considered acute; if it occurs more than three weeks after surgery, it is definite delayed [78–80]. The most common signs and symptoms of SSI are represented by pain, dehiscence and erythema with swelling of the wound, fever and fatigue [60, 63]. If the clinical inspection shows neurological deficits, especially with a reduction of strength and dysesthesia with or without signs of cauda equina syndrome, an epidural abscess should be rapidly investigated [81, 82]. Laboratory tests could show abnormalities in blood count rate (ESR), procalcitonin (PCT) and C-reactive protein (CRP). Blood cultures are documented to be positive in < 50% of the SSI after instrumented spine surgery [83–85]. The most common isolated pathogens that lead to SSI are methicillin-resistant *Streptococcus aureus (MRSA), Streptococcus aureus and Staphylococcus epidermidis* [51, 86, and 87].

NPWT (VAC; Kinetic Concepts Inc., San Antonio, TX, USA) represents a widely used hardware in the management of spinal wound infection [88, 89]. This system consists of a foam dressing that is placed in the wound or over a closed incision with an adhesive transparent membrane [90, 91]. Finally, a vacuum pump is applied above it, creating and maintaining a negative pressure [87, 92]. Before VAC application, an accurate wound debrided and irrigation

Table 1 Generalities, patient characteristics, and main results of the included studies

References	Journal	Study design	Patients (*n*)	Mean age (years)	Women (*n*)	Main findings
Adogwa et al. [43]	*Spine J*	Retrospective	16	50.2	7	NWPT represents a valid treatment strategy for patients with complex postoperative spinal infections, but little is known of the complications associated with its use
Canavese et al. [44]	*J Bone Joint Surg B*	Retrospective	14	13.4	10	NPWT is a useful option in patients with wound infections after spinal surgery, especially those with neuromuscular diseases. It allows for the retention of the instrumentation and the maintenance of spinal correction
Jones et al. [45]	*J Neurosurg Spine*	Retrospective	16	44.8	7	NPWT represents a good tool in the management of SSI after spine surgery. Complications need to be more investigated
Kale et al. [46]	*J Orthop Case Rep*	Retrospective	12	48.0	5	NPWT in the management of SSI after instrumentation spine surgery eliminates need of implant removal and help to salvage instrumented spine. The use of the NPWT looks appealing in patients with comorbidities, since it avoid the need for complex plastic surgery
Karaaslan et al. [47]	*Int Med Case Rep J*	Retrospective	6	55.6	6	A successful treatment of infections after dorsal spine surgery is operative management with repeated second-look operations and copious debridement added to NPWT
Kurra et al. [48]	*Int J Spine Surg*	Retrospective	23	59.0	13	NPWT is useful for managing spinal infections, showing few procedures to ultimately achieve wound closure
Labler et al. [6]	*Eur Spine J*	Retrospective	15	48.0	11	NPWT is a valuable tool for management of dead space and wound conditioning in SSI after spine surgery
Lee et al. [49]	*Eur Spine J*	Prospective	42	57.2	20	The early application of NPWT in SSI after instrumentation spine surgery may help to achieve early resolution of infections
Mehbod et al. [7]	*J Spinal Disord Tech*	Retrospective	20	55.0	8	NPWT represents an effective adjunct in closing complex deep spinal wounds with exposed instrumentation. Physicians may be able to decrease the number of surgeries for repeat debridements
Patel et al. [50]	*Int J Spine Surg*	Case report	1	57.0	1	NPWT represents a valid tool for wound dehiscence or infection in oncological patients which underwent spinal fusion surgery
Ploumis et al. [51]	*J Spinal Disord Tech*	Retrospective	73	58.4	39	The positive culture for MRSA or multiple microorganisms was the factor closest to being responsible for the repeat VAC procedures
Rickert et al. [52]	*J Neurol Surg A Cent Eur Neurosurg*	Retrospective	50	69.0	32	NPWT was an effective therapy for the treatment of wound infections after spinal fusion
Ridwan et al. [53]	*World Neurosurg*	Retrospective	25	69.0	13	NPWT in deep spinal wound infections is safe and efficacious in cases with exposure of the dura or durotomy
Shi et al. [54]	*J Orthop Surg Res*	Retrospective	21	62.9	9	NPWT results effective to treat early deep SSI following posterior lumbar fusion with instrumentation

Table 1 (continued)

References	Journal	Study design	Patients (*n*)	Mean age (years)	Women (*n*)	Main findings
van Rhee et al. [55]	*Spine J*	Retrospective	6	12.6	3	NPWT is a good solution for SSI after instrumented spine fusion in neuromuscular patients
West et al. [56]	*Adv Wound Care*	Retrospective	3	45.3	1	NPWT in SSI after instrumentation spinal procedures is a valid tool in preparing wound closure in a short amount of time
Yuan et al. 8	*Spine (Phila Pa 1976)*	Retrospective	12	53.8	7	NPWT is feasible and effective to treat early deep SSI following instrumentation spine surgery
Zeng et al. [57]	*World Neurosurg*	Retrospective	16	58.0	5	NPWT is an efficient technique for the management of deep SSI after lumbar surgery with instrumentation, resulting also portable and easier to use for postoperative nursing care
Zhang et al. [58]	*Medicine (Baltimore)*	Case report	1	59.0		NPWT is a valid treatment option for SSI after posterior spine surgery, especially for patients requiring retention of internal fixation
Zowolak et al. [59]	*Orthop Rev (Pavia)*	Retrospective	9	68.6	3	Treating SSI following spine surgery in elderly patients could result challenging and difficult. NPWT represents a valid option

with saline solution is recommended. Furthermore, the peri-wound soft tissue has to be dry [85, 93]. There are two kinds of foams: black (Polyurethane ether, used for deep wound infection) and white (Polyvinyl alcohol, used for superficial wound infections) [85, 93]. The negative pressure mode can be continuous or intermittent, ranging from 50 to 175 mmHg [87, 94]. In the treatment of SSI, the consensus indicates a negative pressure of 125 mmHg in adult patients [95, 96]. For children the range spreads from 50 to 125 mmHg, differing in infants, children or adolescents [85, 97]. NPWT is usually changed every 2–5 days [85, 93]. The generated pressure reduces and eventually closes dead spaces, clears bacterial colonization, increases local blood perfusion and minimizes bacterial colonisation. Moreover, NPWT stimulates the removal of exceeded interstitial fluid, leading to the improvement of soft tissue oxygenation as well as lymphatic and microvascular drainage [87, 98]. This helps the formation of granulation tissue, which accelerates wound healing [92, 99]. Morykwas et al. [28] demonstrated that the application of controlled subatmospheric pressure creates an environment that promotes wound healing in a pig model. Armstrong et al. [100] showed a significant association between an increase in granulation tissue formation and a superior rate of wound closure in the NPWT cohort compared to the control cohort using standard wound care.

In most of the reviewed studies included in the present investigation, NPWT proved to be an efficient option in the management of SSI after instrumented spine surgery. Yuan-Innes et al. [101] reported the successful use of NPWT in two patients with infected and exposed spinal hardware. Mehbod et al. [7] reported successful use of NPWT in 20 cases of deep wound infections occurring after spinal fusion surgery. They needed approximately 2.2 (range 2–3) procedures until definitive closure, which occurred on average seven days (range 5–14) after the initial NPWT placement [7]. Removing spinal instrumentation hardware was not needed in any patient [7]. Canavese et al. [44] also reported a positive experience using NPWT in 14 cases of deep wound infection after scoliosis correction surgery in children and adolescents, with neuromuscular or syndromic problems. Also in this series, no patient required the removal of hardware either initially or during follow-up [44]. Rickert et al. [52] also analysed 50 cases of NPWT treatment for deep wound infection after posterior and posterior anterior spinal fusion. All infections were successfully cured and no spinal implants had to be removed in these cases either [52]. Patel et al. [50] reported a case of deep wound infection after metastatic spine tumour surgery with polymicrobial contamination in a 57-year-old woman, which was not responsive to regular debridements and antibiotics. NPWT was applied showing granulation tissue and reduction of inflammatory markers [50]. Finally, the wound was secondarily closed after 14 days [50]. In the systematic review of Khan et al. [102] including 1150 patients, NPWT showed an absolute risk reduction of 16.6% and a relative risk reduction of 40.4% for hardware removal in SSI after posterior instrumented spine surgery.

In comparison to these results, the use of NPWT in patients with an intraoperative cerebrospinal fluid leak (CSF leak) combined with SSI is still debated. Jones et al. [45] recommended the avoidance of NPWT in the presence of CSF leak, since a patient of their series required a ventriculoperitoneal shunt because of postmeningitic nonobstructive hydrocephalus. However, other authors reported no concerns about the use of NPWT in patients with a CSF leak after propal dural closure [49, 53, 103].

NPWT represents a valid and option in the treatment of postoperative spinal wound infections. However, the reported studies do not include a wide number of patients and its use in presence of CSF should be deeply investigated. Moreover, the limited evidence needs to compare the effectiveness of NPWT to other therapy options like continuous irrigation and drainage. A multi-centre prospective randomized controlled trial with a larger sample size should be conducted in the future.

Conclusion

NPWT could be a valuable adjuvant therapy for the management of SSI after spine surgery. Additional high-quality investigations are required to assess the efficacy and safety of NPWT in SSI after spine surgery, especially if combined with contraindications or risk factors, such as the presence of intraoperative CSF leak.

Author contributions Gaetano Pappalardo involved in literature search, data extraction, quality assessment; Sascha Schneider involved in writing; Andreas Kotsias: writing; Madhan Jeyaraman involved in writing; Luise Schäfer involved in literature search, data extraction, quality assessment; Filippo Migliorini involved in writing, statistical analyses. All authors have agreed to the final version to be published and agree to be accountable for all aspects of the work.

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Data availability The datasets generated during and/or analysed during the current study are available throughout the manuscript.

Declarations

Conflict of interest The authors declare that they have any competing interests for this article.

Ethical approval This study complies with ethical standards.

Registration and protocol The present review was not registered.

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