Single-use negative-pressure wound therapy versus conventional dressings for closed surgical incisions: systematic literature review and meta-analysis

C. Saunders 1,*, L. M. Nherera2, A. Horner 1 and P. Trueman 2

1Global Clinical Affairs, Smith+Nephew, Hull, UK
2Health Economics and Market Access, Smith+Nephew, Hull, UK

*Correspondence to: Global Clinical Affairs, Smith+Nephew, 101 Hessle Road, Hull HU3 2BN, UK (e-mail: Christopher.Saunders@smith-nephew.com)

Presented to the 29th Conference of the European Wound Management Association, Gothenburg, Sweden, June 2019

Abstract

Background: Surgical-site complications (SSCs) remain a significant cause of morbidity and mortality, particularly in high-risk patients. The aim of this study was to determine whether prophylactic use of a specific single-use negative-pressure wound therapy (sNPWT) device reduced the incidence of SSCs after closed surgical incisions compared with conventional dressings.

Methods: A systematic literature review was performed using MEDLINE, Embase and the Cochrane Library to identify articles published from January 2011 to August 2018. RCTs and observational studies comparing PICO™ sNPWT with conventional dressings, with at least 10 patients in each treatment arm, were included. Meta-analyses were performed to determine odds ratios (ORs) or mean differences (MDs), as appropriate. PRISMA guidelines were followed. The primary outcome was surgical-site infection (SSI). Secondary outcomes were other SSCs and hospital efficiencies. Risk of bias was assessed.

Results: Of 6197 citations screened, 29 studies enrolling 5614 patients were included in the review; all studies included patients with risk factors for SSCs. sNPWT reduced the number of SSIs (OR 0.37, 95 per cent c.i. 0.28 to 0.50; number needed to treat (NNT) 20). sNPWT reduced the odds of wound dehiscence (OR 0.70, 0.53 to 0.92; NNT 26), seroma (OR 0.23, 0.11 to 0.45; NNT 13) and necrosis (OR 0.11, 0.03 to 0.39; NNT 12). Mean length of hospital stay was shorter in patients who underwent sNPWT (MD –1.75, 95 per cent c.i. –2.69 to –0.81).

Conclusion: Use of the sNPWT device in patients with risk factors reduced the incidence of SSCs and the mean length of hospital stay.

Introduction

Postoperative surgical-site complications (SSCs) represent a significant burden to healthcare systems. SSCs such as surgical-site infection (SSI), dehiscence, seroma and haematoma can delay the healing process, cause abnormal wound healing, and result in the formation of hypertrophic and keloid scars. These complications can result in increased length of hospital stay, higher rates of readmission, and compromised health outcomes, thereby escalating costs associated with a patient’s episode of care. This emphasizes the importance of preventing SSCs to ensure delivery of optimal and cost-effective patient care pathways by healthcare professionals and policy-makers.

The incidence of SSI after surgery is an important outcome measure for the success of a closed surgical-incipision wound management treatment pathway. For this complication in particular, concerns over the increasing prevalence of antibiotic-resistant strains of bacteria necessitates consideration of alternative therapies. There are many factors that can influence wound healing and the potential for infection, including patient-related (high BMI, smoking status, pre-existing comorbidities and high ASA grade) and procedural-related factors (type of surgery, prolonged duration of surgery, use of synthetic implants and increased complexity of surgery). Clear guidance, however, on what constitutes a high-risk patient is currently lacking.

Optimizing wound outcomes is complex and multifactorial, particularly within high-risk patient populations, but single-use negative-pressure wound therapy (sNPWT) devices have emerged as an important technological innovation in wound management. Differences in product specifications between the sNPWT devices offered by different companies, particularly for pressure settings, therapy duration and exudate management, may lead to variations in the clinical benefit offered by each. PICO™ (Smith+Nephew, Hull, UK) is a canister-free sNPWT system consisting of a sterile pump and multilayered adhesive dressings. The device is used in place of conventional postsurgical wound dressings in closed surgical incision wounds with low to moderate exudate level. The dressing can be left in place for up to 7 days, and can be used in both hospital and community settings. Of particular relevance to closed surgical incisions, the system...
contains a unique AIRLOCK™ Technology layer (Smith+Nephew, Hull, UK) that delivers consistent negative pressure across the whole dressing to ensure treatment is delivered to a wider zone beyond the wound itself.

The aim of this study was to determine whether use of the PICO™ system could reduce the incidence of SSCs in comparison with conventional dressings. In addition, the effect on hospital efficiencies was investigated. The review was performed as part of a health technology assessment of the PICO™ NPWT system for the National Institute for Health and Care Excellence (NICE) in England and Wales.

Methods
This review was written in accordance with PRISMA guidelines. Although the review was not preregistered, the protocol and outcomes to be studied were agreed in advance with NICE before conducting the review.

Search strategy
MEDLINE, Embase and the Cochrane Library were searched for relevant articles published between January 2011 to August 2018. Search terms used included ‘negative pressure wound therapy’ OR NPWT OR PICO OR ‘topical negative pressure’. To increase the sensitivity of searches, search terms were intentionally left open and did not include words related to specific outcomes, patient populations or adverse events. Reference lists of included articles were hand-searched to identify any further potentially eligible studies that may have been missed by the database search strategy. Searches were restricted to English-language articles, but no other filters were applied. ClinicalTrials.gov and ISRCTN trial registers were checked to ensure that no additional studies were available.

Study selection
Two experienced data reviewers screened potentially relevant articles independently by examining the titles and abstracts. All abstracts were assessed using the inclusion and exclusion criteria listed in Table 1, and studies were included if they fulfilled the criteria. If either reviewer deemed an article as potentially relevant, the article progressed to full-text screening. In case of disagreement, a third reviewer made the final decision after reading the full-text paper or conference abstract. Included studies compared outcomes following the use of PICO™ versus standard care for closed surgical incisions. The standard of care was defined as the use of standard non-NPWT dressings.

Data extraction and quality assessment
Data were extracted from included studies by one reviewer using a predefined and standardized data extraction form, and checked for accuracy by a second reviewer. Extracted data included descriptions of study characteristics. Study design, location of the study, the number of patients involved and the type of surgery performed were recorded.

The primary outcome of interest for this systematic literature review was the number of patients who had an SSI with PICO™ compared with the standard of care. Secondary outcomes of interest were the number of patients who experienced dehiscence, oedema, seroma, haematoma, skin/fat necrosis, delayed healing or abnormal scarring after surgery. Readmission rates, reoperation rates, number of dressing changes, length of hospital stay and time to heal were recorded. Studies were also screened for reporting of potential device-related issues.

Quality assessment
The reviewers assessed risk of bias for each study, recognizing the challenges of blinding participants to the sNPWT device. For RCTs, Centre for Reviews and Dissemination guidelines for the assessment of risk of bias in RCTs were followed. For observational studies, Critical Appraisal Skills Programme (CASP) guidelines were followed, using criteria that were adopted by NICE for their Medical Technologies Evaluation Programme. Funnel plots were produced to determine potential risk of bias from the cumulative evidence.

Statistical analysis
Meta-analyses were performed in Review Manager® VS.3 (The Nordic Cochrane Centre, Copenhagen, Denmark). Heterogeneity of included studies was assessed using the I² statistic. When I² was less than 50 per cent (indicating no substantial heterogeneity), a fixed-effect model was used; when I² was over 50 per cent, a random-effects model was used. For dichotomous outcomes, NPWT, negative-pressure wound therapy; n.a., not applicable.

Table 1 Inclusion and exclusion criteria used to identify relevant studies for inclusion in the systematic literature review and meta-analysis

| Inclusion criteria | Exclusion criteria |
|--------------------|-------------------|
| Population         | Patients of any age with closed surgical incisions. Patients with any risk factors for complications were also included. |
| Intervention       | PICO™ (Smith+Nephew, Hull, UK) (single-use NPWT) applied after surgery on a closed surgical incision. Participants undergoing any type of operation were eligible, and both prophylactic and reactive use of PICO™ were included. |
| Comparator         | Standard care (any non-NPWT dressing). |
| Outcome            | Surgical-site infections, dehiscence, oedema, seroma, haematoma, skin/fat necrosis, delayed healing, abnormal scarring, readmission rates, length of hospital stay, reoperation rates, number of dressing changes, time to heal. |
| Study design       | RCTs or retrospective/prospective observational studies with at least 10 patients in each treatment arm. |
| Language restrictions | English |
| Search dates       | Studies published from 1 January 2011 to 1 August 2018 |
|                     | Patients with open surgical incisions or any non-surgical wound. |
|                     | Other forms of NPWT (not PICO™) were excluded. |
|                     | Non-standard care |
|                     | n.a. |
|                     | Case reports, case series, studies with fewer than 10 patients in each treatment arm, letters, commentaries, notes, reviews and editorials. |
|                     | Not in English |
|                     | Studies published before 2011. |
the Mantel–Haenszel method was used to combine separate statistics, and the odds ratio (OR) with 95 per cent c.i. was reported as the summary statistic. For continuous outcomes, the inverse variance method was used to combine statistics, and the mean difference (MD) was used and expressed using usual units (for example, days for length of stay). Relative risk was calculated and used in number needed to treat (NNT) calculations.

Sensitivity analyses were performed using alternative pooling methods (for example, Peto method versus Mantel–Haenszel method, applicable to dichotomous data). Further sensitivity analyses were the inclusion and exclusion of conference abstracts and using fixed-effect or random-effects models. P<0.050 denoted statistical significance.

Results
A total of 2564 articles were identified from PubMed, 3219 from Embase, and 414 from the Cochrane Library. A PRISMA diagram of the number of studies at each stage of the process is shown in Fig. 1. After applying the inclusion and exclusion criteria, 29 studies8–36 were selected. Of these studies, 11 were RCTs, 13 were observational studies, and five were available as conference abstracts.

Study characteristics
Key characteristics for each included study are shown in Table S1. These studies represent patients from a wide geographical distribution, including five studies from the UK14,15,17,19,20, two from Ireland11,24, nine from mainland Europe10,18,23,25–27,30,33,34, one from the Nordic region28, six from the USA8,16,21,22,31,36, two from Australia9,13, two from Asia29,32, and one from Mexico. One additional study was a multicentre study incorporating patients from the USA, France, the Netherlands and South Africa. A range of surgical specialties were represented within the identified evidence, including orthopaedics, obstetrics, colorectal, breast, vascular and cardiothoracic surgery. In all studies, factors could be identified that placed the patient populations at higher risk of poor outcomes.
Was an ITT analysis

Have all outcomes

Were any drop-outs

et al.

for the study by Galiano

reporting was considered to be complete for all studies, except RCTs, potentially introducing another source of bias. Outcome intention-to-treat analysis was performed in some, but not all, was the inability to ensure blinding of outcome assessors. An care providers, participants and assessors blinded to treatment allocation?

Were the groups similar at the outset of the study?

Were any drop-outs balanced between groups?

Have all outcomes measured by the authors being reported, or is there evidence to suggest otherwise?

Was an ITT analysis included? If so, were appropriate methods used to account for missing data?

Table 2 Assessment of risk of bias for RCTs included in the analysis

| Chaboyer et al.  | Galiano et al. | Gillespie et al. | Hyldig et al. | Karlakki et al. | Nordmeyer et al. | O’Leary et al. | Svensson-Björk et al. | Tanaydin et al. | Uchino et al. | Witt-Majchrzak et al. |
|------------------|----------------|------------------|--------------|----------------|----------------|---------------|-----------------------|----------------|-------------|------------------------|
| Was the method used to generate random allocations adequate? | Yes | Yes | Yes | Yes | Yes | ? | Yes | Yes | Yes | Yes |
| Was the allocation adequately concealed? | Yes | Yes | Yes | Yes | Yes | ? | Yes | Yes | Yes | Yes |
| Were the groups similar at the outset of the study? | ? | Yes | Yes | Yes | ? | ? | Yes | Yes | Yes | Yes |
| Were care providers, participants and assessors blinded to treatment allocation? | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Were any drop-outs balanced between groups? | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Have all outcomes measured by the authors being reported, or is there evidence to suggest otherwise? | Yes | ? | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Was an ITT analysis included? If so, were appropriate methods used to account for missing data? | No | No | ? | Yes | Yes | No | ? | No | No | Yes |

Quality criteria were taken from Centre for Reviews and Dissemination guidelines for the assessment of risk of bias in RCTs, n.a., not applicable; ITT, intention to treat.

Table 4. Meta-analysis of outcomes of surgical-site complications

| Risk of developing an SSC due to patient- or procedure-related factors. |
|--------------------------|---------------------------|-------------------|-------------------|-------------------|
| Risk of bias and confidence in the evidence |
| The overall quality of the included studies was deemed acceptable (Tables 2 and 3). For RCTs, the largest source of bias identified was the inability to ensure blinding of outcome assessors. An intention-to-treat analysis was performed in some, but not all, RCTs, potentially introducing another source of bias. Outcome reporting was considered to be complete for all studies, except for the study by Galiano et al., in which the results of scar quality were not included. |
| Meta-analysis of outcomes of surgical-site complications |
| An overview of the results from meta-analyses of SSCs is shown in Table 4. Overall, the odds of SSI were reduced by 63 per cent with the use of the PICO™ (OR 0.37, 95 per cent c.i. 0.28 to 0.50), with the corresponding forest plot shown in Fig. 2. This corresponded to a NNT of 20 for this outcome. When the results from RCTs and observational studies were considered in isolation, use of the PICO™ resulted in a reduction of 52 per cent (OR 0.48, 0.33 to 0.71) and 73 per cent (OR 0.27, 0.17 to 0.43) respectively. Sensitivity analyses showed that this statistically significant reduction was maintained when a random-effects model was used instead of a fixed-effect model, and also when data from conference abstracts were included (data not shown). When studies were segmented based on the type of surgery and subanalyses were performed, the significant reduction in SSI was maintained for orthopaedic (OR 0.43, 0.21 to 0.86; NNT 15), breast (OR 0.36, 0.14 to 0.97; NNT 23), vascular (OR 0.22, 0.05 to 0.87; NNT 9) and obstetric (OR 0.49, 0.31 to 0.78; NNT 54) surgery. For colorectal surgery, statistical significance was not reached (OR 0.43, 0.09 to 2.05). When other SSCs were considered, there was a difference in favour of sNPWT for dehiscence (OR 0.70, 95 per cent c.i. 0.53 to 0.92; NNT 26). sNPWT also reduced seroma (OR 0.23, 0.11 to 0.45; NNT 13) and necrosis (OR 0.11, 0.03 to 0.39; NNT 12). Heterogeneity, as indicated by the I² statistic, was considered not significant (less than 50 per cent) in all meta-analyses except from SSI for colorectal surgery (72 per cent), time to healing (86 per cent) and length of hospital stay (92 per cent). All other SSCs analysed (haematoma, delayed healing, abnormal scarring and time to healing) demonstrated no difference between sNPWT and standard of care. Data on the number of dressing changes and oedema were insufficient to perform meta-analyses. When studies were screened for potential device-related adverse events, of the 29 studies described a tenfold of the PICOTM resulted in a reduction of 52 per cent (OR 0.48, 0.33 to 0.71) and length of hospital stay (92 per cent). |
| Meta-analysis of hospital efficiency outcomes |
| As shown in Table 4, length of hospital stay was reduced in patients treated with PICO™ compared with that of patients treated with conventional dressings (MD −1.75, 95 per cent c.i. −2.69 to −0.81). Sensitivity analysis indicated that this difference was maintained regardless of whether a fixed-effect or random-
Table 3 Assessment of risk of bias for observational studies included in the analysis

| Study | Was the cohort recruited in an acceptable way? | Was the exposure accurately measured to minimize bias? | Was the outcome accurately assessed to minimize bias? | Have the authors identified all important confounding factors? | Have the authors taken account of the confounding factors in the design and/or analysis? | Was the follow-up of patients complete? | Are the results precise (for example, were confidence intervals and values provided)? |
|-------|-----------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|-------------------------------------------------|-------------------------------------------------|---------------------------------|-------------------------------------------------|
| Adogwa et al. | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | ?                                                                 |
| Dingemans et al. | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |
| Fleming et al.    | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | No                                               |
| Gupta et al.       | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | No                                               |
| Hester et al.      | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |
| Hickson et al.     | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |
| Holt and Murphy    | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |
| Matsumoto and Parekh | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |
| Pellino et al.     | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |
| Pellino et al.     | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |
| Selvaggi et al.    | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |
| Tan et al.         | Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |
| van der Valk et al.| Yes                                            | Yes                                                  | Yes                                                  | Yes                                             | Yes                                             | Yes                             | Yes                                               |

Criteria were adapted from Critical Appraisal Skills Programme guidelines. ?, Partial or unclear.

Table 4 Results of meta-analyses performed for surgical-site complications

| Outcome or subgroup | No. of studies | No. of participants | Statistical method | $I^2$ statistic (%) | Effect estimate | P |
|---------------------|----------------|---------------------|--------------------|---------------------|-----------------|---|
| SSI (all operations) | 19             | 4530                | OR (M–H, fixed effect, 95% c.i.) | 30 | 0.37 (0.28, 0.50) | <0.001 |
| Orthopaedic surgery SSI | 5              | 607                 | OR (M–H, fixed effect, 95% c.i.) | 0  | 0.43 (0.21, 0.86) | 0.02  |
| Colorectal surgery SSI | 5              | 220                 | OR (M–H, random effects, 95% c.i.) | 72 | 0.43 (0.09, 2.05) | 0.29  |
| Obstetric surgery SSI | 3              | 2911                | OR (M–H, fixed effect, 95% c.i.) | 0  | 0.49 (0.31, 0.78) | 0.003  |
| Breast surgery SSI  | 2              | 420                 | OR (M–H, fixed effect, 95% c.i.) | 46 | 0.36 (0.14, 0.97) | 0.04  |
| Vascular surgery SSI | 2              | 193                 | OR (M–H, fixed effect, 95% c.i.) | 11 | 0.22 (0.06, 0.87) | 0.03  |
| Cardiothoracic surgery SSI | 34         | 1                   | OR (M–H, fixed effect, 95% c.i.) | n.a | 0.12 (0.01, 1.03) | 0.05  |
| Mixed surgery SSI | 1              | 49                  | OR (M–H, fixed effect, 95% c.i.) | n.a | 0.19 (0.04, 1.03) | 0.05  |
| Dehiscence | 9              | 1790                | OR (M–H, fixed effect, 95% c.i.) | 0  | 0.70 (0.53, 0.92) | 0.01  |
| Seroma | 6              | 771                 | OR (M–H, fixed effect, 95% c.i.) | 17 | 0.23 (0.11, 0.45) | <0.001  |
| Haematoma | 3              | 591                 | OR (M–H, fixed effect, 95% c.i.) | 0  | 1.02 (0.35, 2.97) | 0.96  |
| Time to healing | 3              | 259                 | MD (IV, random effects, 95% c.i.) | 86 | 17.91 (~4.44, 48.81) | 0.19  |
| Delayed healing | 3              | 627                 | OR (M–H, fixed effect, 95% c.i.) | 0  | 0.77 (0.51, 1.16) | 0.21  |
| Necrosis | 2              | 474                 | OR (M–H, fixed effect, 95% c.i.) | 38 | 0.11 (0.03, 0.39) | <0.001  |
| Abnormal scarring | 1              | 80                  | OR (M–H, fixed effect, 95% c.i.) | n.a | 0.38 (0.09, 1.60) | 0.19  |
| Length of stay | 10             | 948                 | MD (IV, random effects, 95% c.i.) | 92 | 1.75 (~2.69, ~0.81) | <0.001  |
| Readmission rates | 9              | 966                 | OR (M–H, fixed effect, 95% c.i.) | 0  | 0.82 (0.49, 1.38) | 0.45  |
| Reoperation rates | 9              | 1385                | OR (M–H, fixed effect, 95% c.i.) | 0  | 0.92 (0.54, 1.56) | 0.75  |

Values in parentheses are 95% confidence intervals. SSI, surgical-site infection; OR, odds ratio; M–H, Mantel–Haenszel; n.a., not applicable; MD, mean difference; IV, inverse variance.
Effects model was used. No difference was found in readmission (OR 0.82, 0.49 to 1.38) or reoperation (OR 0.92, 0.54 to 1.56) rate.

Publication bias

A funnel plot was produced to assess for publication bias in the 19 included clinical studies used in the comparison of SSI outcome (Fig. 3). The distribution of studies was approximately symmetrical, although RCTs were more predominant on the right side of the graph and observational studies more predominant on the left. All but one study lay within the region where 95 per cent of studies were predicted to be in the absence of bias and heterogeneity.

Discussion

In this meta-analysis, sNPWT reduced several clinically important SSCs, including SSI, dehiscence, seroma and necrosis, compared with standard of care. For SSI specifically, this reduction was seen across a range of surgical specialties, including orthopaedics, breast surgery, vascular surgery and obstetrics. In addition, sNPWT reduced the length of hospital stay.

All studies included in the present analysis had patient populations with risk factors for SSCs, although the exact criteria used to define a patient as high risk differed between studies. This was likely due to lack of guidance on how to identify clearly patients at high risk of SSCs and, as a result, the patients within each study may have had differing risk profiles for developing complications. Thus, there may be clinical heterogeneity between studies, and this should be considered when extrapolating the results to local practice. It has been shown in subgroup analyses presented by Galiano and colleagues and Pellino et al. that PICOTM may have increasing benefit over the standard of care with increasing patient age and BMI. Thus, the absolute percentage reduction reported for complications such as SSI and wound dehiscence may differ, depending on the risk profile of an individual patient. It is likely to be the case that patients with more risk factors may see a greater reduction in the incidence of SSCs.
Subgroup analyses support the use of sNPWT to reduce SSIs for certain specialties. The variability of risk factors present within the patient cohorts of each study makes it difficult to estimate the size of the effect for each surgical procedure separately. However, SSCs are a common concern across different surgical specialties, and the mechanism of action of PICO™ on a surgical incision should be transferable between different procedures.

The bias assessment performed revealed some potential sources of bias that should be considered. In most cases it was not possible to blind the patient and treating clinician to treatment assignment, owing to the nature of the device. The use of a sham device could have been possible, and was considered by the assignments, owing to the nature of the device. The use of a sham incision should be transferable between different procedures.

2. Korol E, Johnston K, Waser N, Sifakis F, Jafari HS, Lo M et al. A systematic review of risk factors associated with surgical site infections among surgical patients. PLoS One 2013;8:e83743

3. Gillespie B, Finigan T, Kerr D, Lonie G, Chaboyer W. End-users’ assessment of prophylactic negative pressure wound therapy products. Wound Pract Res 2013;21:74–81

4. Ambler G, Casey C. Fluid Handling and Negative Pressure Delivery in a Multi-layered Absorbent AIRLOCK Technology Dressing. Krakow: European Wound Management Association, 2018

5. Moher D, Liberati A, Tetzlaff J, Altman D; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol 2009;62:1006–1012

6. Centre for Reviews and Dissemination. Systematic Reviews: CRD’s Guidance for Undertaking Reviews in Health Care. https://www.york.ac.uk/media/crd/Systematic_Reviews.pdf (accessed 1 August 2019)

7. Critical Appraisals Skills Programme. CASP Checklist: 12 Questions to Help You Make Sense of a Cohort Study. https://casp-uk.net/wp-content/uploads/2016/01/CASP-Cohort-Study-Checklist_2018.pdf (accessed 1 August 2019)

8. Adogwa O, Fatemi P, Perez E, Moreno J, Chagoya Gazcon G, Gokaslan ZL et al. Negative pressure wound therapy reduces incidence of postoperative wound infection and dehiscence after long-segment thoracolumbar spinal fusion: a single institutional experience. Spine J 2014;14:2911–2917

9. Chaboyer W, Anderson V, Webster J, Sneddon A, Thalib L, Gillespie BM. Negative pressure wound therapy on surgical site infections in women undergoing elective caesarean sections: a pilot RCT. Healthcare (Basel) 2014;2:417–428

10. Dingemans S, Birnie M, Backes M, de Jong VM, Luitse JS, Carel Goslings J et al. Prophylactic negative pressure wound therapy after lower extremity fracture surgery: a pilot study. Int Orthop 2018;42:747–753

11. Fleming CA, Kuteva M, O’Hanlon K, Bhandari M, McGreal G. Routine use of PICO dressings may reduce overall groin wound complication rates following peripheral vascular surgery. J Hosp Infect 2018;99:75–80

12. Galiano R, Hudson D, Shin J, van der Hulst R, Tanaydin V, Djohan R et al. Incisional negative pressure wound therapy for prevention of wound healing complications following reduction mammoplasty. Plast Reconstr Surg Glob Open 2018;6:e1560

13. Gillespie B, Rickard CM, Thalib L, Kang E, Finigan T, Homer A et al. Use of negative-pressure wound dressings to prevent surgical site complications after primary hip arthroplasty: a pilot RCT. Surg Innov 2019;22:488–495

14. Hackney L, McCoubrey A. The effect of negative pressure dressings (PICO) on wound complications, readmission rates and length of stay. 12th Scientific and Annual Meeting of the European Society of Coloproctology, Berlin, 2017

15. Hester T, Mahmood S, Moftah F. Is single use portable incisional negative pressure wound therapy system suitable for revision arthroplasty? Adv Orthop Surg 2015;2015:247324

16. Hickson E, Harris J, Brett D. A journey to zero: reduction of post-operative cesarean surgical site infections over a five-year period. Surg Infect (Larchmt) 2015;16:174–177

17. Holt R, Murphy J. PICO incision closure in oncoplastic breast surgery: a case series. Br J Hosp Med (Lond) 2015;76:217–223

18. Hyldig N, Vinter C, Kruse M, Mogensen O, Bille C, Sorensen J et al. Prophylactic incisional negative pressure wound therapy reduces the risk of surgical site infection after caesarean section in obese women: a pragmatic randomised clinical trial. BJOG 2019;126:628–635

19. Irwin G, Highton L, Murphy J. Negative pressure dressings significantly decrease rates of wound breakdown and may reduce implant loss rates in prepectoral breast reconstruction. Association of Breast Surgery Conference, Birmingham, 2018

20. Karlakki SL, Hamad AK, Whittall C, Graham NM, Banerjee RD, Kuiper JH. Incisional negative pressure wound therapy dressings (NPWTd)
in routine primary hip and knee arthroplasties: a randomised controlled trial. *Bone Joint Res* 2016;5:328–337
21. Kawakita T, Iqbal S, Desale S, Overcash R. Negative pressure wound therapy (PICO) in morbidly obese women after cesarean delivery compared with standard dressing. 38th Annual Meeting of the Society for Maternal–Fetal Medicine, Dallas, 2018
22. Matsumoto T, Parekh SG. Use of negative pressure wound therapy on closed surgical incision after total ankle arthroplasty. *Foot Ankle Int* 2015;36:787–794
23. Nordmeyer M, Pauser J, Biber R, Jantsch J, Lehrf S, Kopschina C et al. Negative pressure wound therapy for seroma prevention and surgical incision treatment in spinal fracture care. *Int Wound J* 2016;13:1176–1179
24. O’Leary DP, Peirce C, Anglim B, Burton M, Concannon E, Carter M et al. Prophylactic negative pressure dressing use in closed laparotomy wounds following abdominal operations: a randomized, controlled, open-label trial: the P.I.C.O. trial. *Ann Surg* 2017;265:1082–1086
25. Pellino G, Sciaudone G, Candilio G, Campitiello F, Selvaggi F, Canonico S. Effects of a new pocket device for negative pressure wound therapy on surgical wounds of patients affected with Crohn’s disease: a pilot trial. *Surg Innov* 2014;21:204–212
26. Pellino G, Sciaudone G, Candilio G, De Fatico GS, Landino I, Della Corte A et al. Preventive NPWT over closed incisions in general surgery: does age matter? *Int J Surg* 2014;12(Suppl 2):S64–S68
27. Selvaggi F, Pellino G, Sciaudone G, Della Corte A, Candilio G, Campitiello F et al. New advances in negative pressure wound therapy (NPWT) for surgical wounds of patients affected with Crohn’s disease. *Surg Technol Int* 2014;24:83–89
28. Svensson-Björk R, Hasselmann J, Acosta S. Evaluation of inguinal vascular surgical scars treated with closed incisional negative pressure wound therapy using three-dimensional digital imaging—a randomized controlled trial on bilateral incisions. *Wound Repair Regen* 2018;26:7–86
29. Tan KW, Lo ZJ, Hong Q, Narayanan S, Tan GWL, Chandrasekar S. Use of negative pressure wound therapy for lower limb bypass incisions. *Ann Vasc Dis* 2017;10:386–390
30. Tanaydin V, Beugels J, Andriessen A, Savor JH, van der Hulst RRWJ. Randomized controlled study comparing disposable negative-pressure wound therapy with standard care in bilateral breast reduction mammoplasty evaluating surgical site complications and scar quality. *Aesthetic Plast Surg* 2018;42:927–935
31. Tuuli MG, Martin S, Stout MJ, Steiner HL, Harper LM, Longo S et al. Pilot randomized trial of prophylactic negative pressure wound therapy in obese women after cesarean delivery. 37th Annual Meeting of the Society for Maternal–Fetal Medicine, Las Vegas, 2017
32. Uchino M, Hirose K, Bando T, Chohno T, Takesue Y, Ikeuchi H. Randomized controlled trial of prophylactic negative-pressure wound therapy at ostomy closure for the prevention of delayed wound healing and surgical site infection in patients with ulcerative colitis. *Dig Surg* 2016;33:449–454
33. van der Valk MJM, de Graaf EJR, Doornbosch PG, Vermaas M. Incisional negative-pressure wound therapy for perineal wounds after abdominoperineal resection for rectal cancer, a pilot study. *Adv Wound Care (New Rochelle)* 2017;6:425–429
34. Witt-Majchrzak A, Zelazny P, Snarska J. Preliminary outcome of treatment of postoperative primarily closed sternotomy wounds treated using negative pressure wound therapy. *Pol Przegl Chir* 2015;86:456–465
35. Zotes V, Mier J, Cortes G. Negative pressure wound therapy in a potentially infected wound after empyema surgery. 23rd European Conference on General Thoracic Surgery, Lisbon, 2015.
36. Gupta R, Darby GC, Imagawa DK. Efficacy of negative pressure wound treatment in preventing surgical site infections after Whipple procedures. *Am Surg* 2017;83:1166–1169