

Evidence note 88: Negative Pressure Wound Therapy (NPWT)

Appendix 1: Review of clinical effectiveness evidence

The evidence review in this appendix supplements the clinical effectiveness summary on negative pressure wound therapy (NPWT) published in Evidence Note 88. In this appendix, evidence from the extensive literature identified on this topic is considered in more detail. For each wound type the key findings from the 2010 health technology assessment (HTA) by Quality Improvement Scotland¹ are reported, followed by evidence from studies published after the HTA (2013-2018) and an assessment of the current status of NPWT for each wound type based on the updated evidence.

Chronic wounds: pressure ulcers

Main findings from 2010 HTA

The HTA published in 2010 identified some RCT evidence relating to the use of NPWT in pressure ulcers¹. However the methodological quality of the studies was poor, and the results were inconsistent.

Literature published after 2010 HTA

A search for secondary evidence, limited to the last five years (2013-2018) highlighted a Cochrane review by Dumville *et al* (2015) which assessed the effects of NPWT for treating pressure ulcers. It included four RCTs, encompassing 149 participants. However, these were deemed to be of very low quality, with the authors concluding that “high uncertainty remains about the potential benefits or harms, or both, of using this treatment for pressure ulcer management”².

Two additional systematic reviews were identified but these do not alter the conclusions of the Cochrane review^{3,4}.

Guidance from the National Institute for Health and Care Excellence (NICE) from 2014 states that there is limited evidence to support the use of NPWT on pressure ulcers⁵. It makes the following two recommendations:

- “Do not routinely offer adults negative pressure wound therapy to treat a pressure ulcer, unless it is necessary to reduce the number of dressing changes (for example, in a wound with a large amount of exudate).”
- “Do not routinely use negative pressure wound therapy to treat a pressure ulcer in neonates, infants, children and young people.”

Our literature search did not identify any RCTs on the use of NPWT in pressure ulcers not already included in the systematic reviews.

Current position in light of new evidence

NPWT is used on pressure ulcers in NHS Scotland, however there is limited evidence to support this use. The HTA from 2010 noted a lack of good quality evidence, and this conclusion was echoed in the Cochrane review from 2015.

Chronic wounds: venous leg ulcers

Main findings from 2010 HTA

The HTA published in 2010 identified one ‘reasonable quality’ RCT (n=60) which suggested that venous leg ulcers receiving a split-thickness skin graft may heal more quickly when pre-treated with NPWT rather than hydrogel/alginate with compression¹. However, for venous leg ulcers not being grafted, no useful evidence was found on NPWT. A Scottish Intercollegiate Guidelines Network (SIGN) guideline published in the same year, and based on the same RCT, concluded that “there is insufficient evidence on which to base a recommendation for TNP/VAC in chronic venous leg ulcer”⁶.

Literature published after 2010 HTA

A Cochrane review by Dumville *et al* (2015) assessed the effects of NPWT for treating leg ulcers in any care setting⁷. The review highlighted only the RCT that was included in the 2010 HTA and SIGN guidelines, and so reported the same conclusions as the 2010 publication.

Three older systematic reviews were identified, but these did not include any RCTs other than the one already identified^{3, 4, 8}.

The recent literature search did not identify any RCTs on the use of NPWT in venous leg ulcers that had not been included in the systematic reviews.

Current position in light of new evidence

NPWT is used on venous leg ulcers in NHS Scotland, however there is limited evidence to support this use. Systematic reviews published since the 2010 HTA found no new RCT evidence. Therefore, the conclusion that there is insufficient evidence on which to base a recommendation on NPWT for venous ulcers remains unchanged.

Chronic wounds: wounds associated with diabetes mellitus

Main findings from 2010 HTA

With regards to wounds associated with diabetes mellitus, the main conclusion of the HTA published in 2010 was that foot wounds “may be more likely to heal, and heal more quickly, when treated with TNP versus other modalities”¹. This was largely based on four RCTs (three of which were described as having methodological flaws, and one described as ‘reasonable’ in quality). In the same year, SIGN produced guidelines on the management of diabetes, and recommended that NPWT “should be considered in patients with active diabetic foot ulcers or postoperative wounds”⁹. Similarly, NICE

guidelines from 2010 recommended that NPWT is considered after surgical debridement of foot ulcers associated with diabetes.

Literature published after 2010 HTA

A search limited to the last five years (2013-2018) highlighted eight systematic reviews which evaluated the use of NPWT in people with wounds associated with diabetes mellitus^{3, 4, 8, 10-14}.

The most recent was a systematic review (with meta-analyses) from 2017¹³. The aim was to: “assess the clinical efficacy, safety, and cost-effectiveness of NPWT in the treatment of diabetic foot ulcers”¹³. The review appears to be of good quality, with clearly described methodology. It included 11 RCTs (encompassing 1044 patients), nearly all of which were rated as having an unclear risk of bias relating to the blinding of study participants and personnel, and blinding of outcome assessment. The review authors stated that the comparator was ‘standard dressing changes’. In the individual studies, the comparators were described as: ‘standard moist wound care’; ‘advanced moist wound therapy’; ‘conventional wound treatment’; ‘conventional moist dressings’; ‘standard wound dressings’; ‘saline-moistened gauze’; and ‘moist dressings’. The review reported the following results:

- Complete healing rate: The results from five studies were pooled, and compared to standard dressing changes, NPWT had a higher rate of complete healing of ulcers (relative risk (RR) 1.48; 95% confidence interval (CI) 1.24 to 1.76; $p < 0.001$).
- Time to complete healing: The results from two studies were pooled, suggesting NPWT had a shorter time to complete healing ulcers compared to standard dressings (mean difference - 8.07; 95% CI -13.7 to -2.45; $p = 0.005$).
- Change in ulcer size: The results from six studies were pooled, and NPWT had a greater reduction in ulcer area compared with standard dressings (mean difference 12.18cm²; 95% CI 8.5 to 15.86; $p < 0.00001$). The pooled results from three studies suggested that NPWT also resulted in a greater reduction in ulcer depth (mean difference 40.82mm; 95% CI 35.97 to 45.67; $p < 0.00001$).
- Granulation tissue formation: Four studies assessed granulation tissue formation, but were not suitable to be combined in a meta-analysis. All four studies suggested that granulation tissue formed faster in the NPWT group.
- Quality of life: This was reported in one study, assessed using the SF-36 short form health survey. The results showed that those treated with NPWT scored higher for both mental ($p = 0.0287$) and physical ($p = 0.004$) health compared to conventional wound dressings.
- Resource use: Two studies reported that NPWT was the more cost-effective option, however, further details would be required to clarify this.
- Amputation: The results of three studies were pooled, suggesting fewer amputations in the NPWT group (RR 0.31; 95% CI 0.15 to 0.62; $p = 0.001$).

- Treatment-related adverse events: The results from three studies suggested that there was no difference in treatment-related adverse events in the NPWT and standard dressings groups (RR 1.12; 95% CI 0.66 to 1.89; p=0.68).

The authors concluded that “this meta-analysis of eleven RCTs extends support for the use of NPWT in the treatment of DFUs [*diabetic foot ulcers*] and post-operative wounds in diabetic patients. Additional robust RCT research is necessary to solidify support for the treatment.”¹³

Similar conclusions were reached in six of the other reviews; that there is moderate-quality evidence supporting the use of NPWT compared to conventional treatments in wounds associated with diabetes. However, some of the reviews also suggested that the current RCT evidence was limited, with possible bias, and that further trials were required^{3, 8, 10-12, 14}. The remaining review evaluated the efficacy and safety of NPWT for the treatment of chronic wounds in the home setting. The authors only identified three observational studies, and concluded that they were “unable to draw conclusions about the efficacy or safety of NPWT for the treatment of chronic wounds in the home setting...”⁴.

NICE Guidelines on the prevention and management of diabetic foot problems (2015) recommended that NPWT should be considered after surgical debridement for foot ulcers associated with diabetes, on the advice of the multidisciplinary foot care service¹⁵.

Our literature search did not identify any RCTs on the use of NPWT in ulcers associated with diabetes that had not already been included in the systematic reviews.

Current position in light of new evidence

Additional RCTs and systematic reviews on NPWT for diabetes associated wounds have been published since the HTA in 2010. The findings support the use of NPWT in people who have wounds associated with diabetes mellitus. However, the authors of reviews have highlighted the need for further robust RCT research.

Acute wounds: burns

Main findings from 2010 HTA

The 2010 HTA included a Cochrane review, which included one ‘methodologically weak’ RCT published as an abstract¹. Therefore, the HTA concluded that there was no useful evidence on the use of NPWT as the primary treatment of burns.

Literature published after 2010 HTA

A Cochrane review by Dumville *et al* (2014) identified only the RCT published as a conference abstract, which was reported on in the 2010 review and HTA. Therefore the authors stated that in the absence of completed RCTs on NPWT for partial-thickness burn injury conclusions cannot be drawn on the merits – or otherwise – of this treatment¹⁶. An HTA from Malaysia, published in 2013, reiterated the same conclusions as the 2010 HTA and review by Dumville *et al* (2014)³.

The recent literature search did not identify any additional RCTs on the use of NPWT in burns.

Current position in light of new evidence

A review of the evidence published between 2013 and 2018 highlighted no new RCTs on the use of NPWT as the primary treatment of burns. Therefore, recommendations are not possible supporting or refuting its use in this patient group.

Acute wounds: trauma wounds

Main findings from 2010 HTA

Based on two randomised studies by the same author, the 2010 HTA concluded that: “Trauma wounds may drain more quickly with TNP than pressure dressings. No difference was found in wound infections and breakdown. For surgical incisions or fractures deemed at high risk of healing problems, wounds may drain more quickly with TNP. No difference was found in wound infections or repeat surgery.”¹

Literature published after 2010 HTA

For open fracture wounds that have been debrided but are still waiting for soft tissue cover, NICE guidance [fractures (complex): assessment and management; 2016] recommends that NPWT is considered as an intermediate wound dressing prior to further surgical intervention¹⁷. This recommendation is based on evidence that was rated as low or very low in quality.

A good quality systematic review from 2018 by Liu *et al* evaluated the use of NPWT in open fractures compared with conventional wound dressings¹⁸. It included eight RCTs (encompassing 421 patients) and six retrospective cohort studies (encompassing 488 patients). All RCTs were rated as having an unclear risk of bias, apart from two that had a high risk of bias. Of the eight RCTs, only one was included in the 2010 HTA, with the remaining seven being published between 2013 and 2017. The following results were reported in the systematic review:

- The pooled estimates from the RCTs (OR 0.17, 95% CI 0.09 to 0.32, $p < 0.00001$) and the retrospective cohort studies (OR 0.26, 95% CI 0.16 to 0.42, $p < 0.00001$) indicated a lower infection rate in the NPWT treatment groups.
- The RCTs reported that compared to conventional wound dressings, NPWT resulted in significantly shorter wound coverage times (the time between initial injury and time when the wound was ready for safe closure), complete wound healing time, and length of hospital stay. Conversely, four retrospective cohort studies reported that NPWT resulted in longer wound coverage times, and three retrospective cohort studies reported that NPWT resulted in a longer length of hospital stay.
- The amputation rate was only reported in two retrospective cohort studies (encompassing 128 patients), with pooled results indicating a higher amputation rate in the conventional wound dressings group (OR=0.15, 95% CI 0.02 to 0.89, $p=0.04$).
- One RCT reported on patient quality of life. There was a significant difference in favour of NPWT in the physical health component of SF-36 scores at 3, 6 and 9 months after surgery.
- No statistically significant difference was found in the need for flap surgery, the proportion of free flaps, the flap failure rate or the fracture non-union rate.

The authors are appropriately cautious in their conclusions, noting the potential for bias in the included studies and the need for good quality RCTs before robust conclusions are possible (particularly with regards to effects on flaps, fracture healing and patient quality of life). They state that there is some evidence which indicates that NPWT reduces the risk of infection in the treatment of open fractures and accelerates their wound healing process. They also note that there is some (but not much) evidence that NPWT may help reduce the risk of amputation.

Another systematic review published in 2015 included one RCT and 12 retrospective studies¹⁹. Only the RCT and three of the retrospective cohorts were included in Liu *et al*¹⁸. This review aimed to assess whether: NPWT in Grade IIIB tibia fractures compared with gauze dressings lead to fewer infections; NPWT allowed flap procedures to be performed beyond 72 hours without increased infection rates; and whether NPWT was associated with fewer local or free flap procedures. The conclusions are similar to those reported by Liu *et al*: “There is an association with decreased infection rates with negative pressure wound therapy [NPWT] compared with gauze dressings. There is evidence to support negative pressure wound therapy beyond 72 hours without increased infection rates and to support a reduction in flap rates...However, negative pressure wound therapy use for Grade IIIB tibia fractures requires extensive additional study.”¹⁸

A search for recent RCTs highlighted a study by Costa *et al* (2018), which aimed to assess the impact of treatment with NPWT on disability, rate of deep infection, and quality of life in patients with severe open fracture of the lower limb, compared with standard wound management after the first surgical debridement of the wound²⁰. It included 460 patients, 226 of which were treated with NPWT. The authors concluded that there were no statistically significant differences in the patients’ Disability Rating Index score at 12 months (MD -3.9; 95% CI -8.9 to 1.2, $p=0.13$); in the number of deep surgical site infections (MD 1%; 95% CI -4.2% to 6.3%; $p=0.64$); in the number of wounds healed at 6 weeks (odds ratio (OR) 1.0; 95% CI 0.6 to 1.6; $p=0.99$); and in quality of life (MD in EuroQol 5-

dimensions score 0.02; 95% CI -0.05 to 0.08; $p=0.82$). The authors concluded that among this patient group, NPWT compared with standard wound dressing did not improve self-rated disability at 12 months, and that their findings do not support the use of this treatment in open fractures. This study appears to have been well conducted, with transparent and clear reporting of the methods and results.

After this evidence note was drafted, a Cochrane review was published on the use of NPWT in treating open traumatic wounds (Iheozor-Ejiofor Z et al, 2018)²¹. The authors evaluated the evidence for open fracture wounds and other open traumatic wounds (no broken bones) separately. For open fracture wounds, four studies were included (including Costa et al). For risk of wound infection, pooled data from the four studies ($n=596$) highlighted no statistically significant difference between groups treated with NPWT at 125mmHg and standard care (relative risk (RR) 0.48, 95% confidence interval (CI) 0.20 to 1.13; $I^2=56\%$; very low certainty evidence). Other outcomes were reported from the individual studies – but have already been covered in this evidence note. For other traumatic wounds, data from two studies were pooled ($n=509$), also suggesting no clear difference in risk of wound infection between open traumatic wounds treated with NPWT at 125mmHg or standard care (RR 0.61, 95% CI 0.31 to 1.18; low certainty evidence). The authors concluded that for open fracture wounds there was moderate-certainty evidence of no clear difference between NPWT and standard care in the proportion of wounds healed at 6 weeks (based on the Costa et al study). They also conclude that there is moderate certainty evidence that NPWT is not a cost-effective treatment for open fracture wounds (also based on the Costa et al study – see cost effectiveness section for more details). Finally, the review authors conclude that “it is uncertain whether there is a difference in risk of wound infection, adverse events, time to closure or coverage surgery, pain or health-related quality of life between NPWT and standard care for any type of open traumatic wound”.

Current position in light of new evidence

Recently published systematic reviews include RCTs which, for some outcomes, support the use of NPWT in the treatment of open fractures/grade IIIB tibia fractures, particularly with regards to decreased infection rates. However, these RCTs were rated as having an unclear or high risk of bias by the systematic review authors. In addition, results from an RCT published after the systematic reviews do not support the use of NPWT in severe open fractures of the lower limbs.

Surgical wounds: open abdomen

Main findings from 2010 HTA

The 2010 HTA identified four systematic reviews on the use of NPWT in open abdominal wounds, but these included a small number of methodologically weak studies¹. Based on these the HTA concluded that open abdominal wounds with peritonitis may be associated with lower mortality when treated with NPWT compared with conventional therapy. However, the need for good quality trials was noted.

Literature published after 2010 HTA

A systematic review by Cirocchi *et al* (2016) evaluated the effectiveness of NPWT compared to non-NPWT therapies in patients treated with open abdomen technique²². It included eight studies (two randomised, two prospective cohorts, and four retrospective cohorts) encompassing 723 patients who had NPWT and 502 patients who did not. The authors stated that the risk of bias in the RCTs was high, and all but one of the cohort studies were rated as 'fair' quality. Clinical heterogeneity between the studies was also noted, for example with respect to the variability in NPWT systems and in the comparator groups. The authors reported on four comparisons:

- VAC versus Bogota bag technique (two studies, 106 participants)
- VAC versus mesh-foil laparostomy (two studies, 159 participants)
- VAC versus laparostomy – adhesive impermeable with midline zip (one study, 106 participants)
- NPWT versus no NPWT (three studies, 854 participants).

Comparing the NPWT group to the comparator groups (combined), there were no statistically significant differences in:

- Fascial closure (63.5% versus 69.5%; OR 0.74, 95% CI 0.27 to 2.06, $p=0.57$).
- Postoperative 30-day overall morbidity ($p=0.19$; data from one study).
- Postoperative enteroatmospheric fistulae rate (2.1% versus 5.8%; OR 0.63, 95% CI 0.12 to 3.15, $p=0.57$).
- Postoperative bleeding rate (5.7% versus 14.9%; OR 0.58, 95% CI 0.05 to 6.84, $p=0.87$).
- Postoperative abdominal abscess rate (2.4% versus 5.6%; OR 0.42, 95% CI 0.13 to 1.34, $p=0.14$).

However, there was a statistically significant difference between the groups favouring NPWT for:

- Postoperative mortality rate (28.5% versus 41.4%; OR 0.46, 95% CI 0.23 to 0.91, $p=0.03$; $I^2=72%$);
- Length of stay in the intensive care unit (mean difference -4.53 days; 95% CI -5.46 to -3.60, $p<0.00001$).

The authors note that for several outcomes the confidence intervals were wide and inconsistency was high. They also combined RCT data with cohort studies in meta-analyses, and the methodological appropriateness of this is questionable. Based on the results the authors conclude that from the current available data NPWT seems to be associated with a trend toward better outcomes compared to the use of no NPWT. However, they stress the need for caution given the weaknesses in the studies and the clinical and statistical heterogeneity. They highlight the need for RCTs in this area. This review is well reported, and the conclusions are appropriately cautious.

Two additional systematic reviews of observational studies were identified, but these were focused on modified NPWT techniques. In one review, the comparison appears to be between NPWT plus continuous fascial traction (NPWT + CFT) and NPWT alone²³. In the other, the focus is on NPWT combined with mesh-mediated fascial traction²⁴. These have not been considered further in this evidence review.

NICE Guidance (2013) states that the current evidence on NPWT for the open abdomen “is adequate to support the use of this procedure provided that normal arrangements are in place for consent, audit and clinical governance”²⁵. The guidance also states that the procedure should only be carried out by healthcare professionals with specific training, and encourages further research into the role of NPWT for the open abdomen. The guidance is based on a systematic review from 2012, two RCTs (one of which is included in the 2012 systematic review), two non-randomised comparative studies and two case series.

Our literature search did not identify any additional RCTs on the use of NPWT in open abdomen.

Current position in light of new evidence

The evidence supporting the use of NPWT in the open abdomen is weak, but suggests that NPWT may be associated with better outcomes compared to the use of no NPWT.

Surgical wounds: skin grafts and surgical wounds healing by primary intention

Main findings from 2010 HTA

Apart from skin grafts, this patient group was not included in the 2010 HTA.

Skin grafts: Six systematic reviews that evaluated the use of NPWT in skin grafts were cited in the 2010 HTA. However these all seemed to draw on the same RCTs, two of which met the inclusion criteria of the HTA. One RCT (n=60) reported that in a burns unit, NPWT led to less graft loss, reduced frequency of re-grafting, and reduced time from intervention to patient discharge. The other (n=22) compared NPWT with bolster dressings and reported that NPWT did not significantly improve take rates - although it appeared to offer an advantage in the quality of graft take. Some additional non-randomised trials were included, and the results were inconsistent.

Literature published after HTA

The most comprehensive review identified for this patient group was a Cochrane review from 2014 (Webster *et al*) which assessed the effects of NPWT on surgical wounds that were expected to heal by primary intention (primary closure, skin grafting or flap closure)²⁶. Fifteen additional reviews were identified, considering a variety of different patient groups²⁷⁻³⁹. In addition, seven RCTs not included in the reviews were identified. Synthesising the reviews and RCTs was challenging, largely because the patient group they considered varied and overlapped. Given the disparity of the studies, for simplicity they have been summarised in table 1. The reviews/studies have been split into categories

to help summarise them, but these categories are imperfect and there is considerable overlap in the patient groups. A fuller description of the reviews, and additional RCTs identified, follows table 1.

Table 1: Summary of reviews and RCTs on skin grafts and surgical wounds healing by primary intention

Patient group	Review references	RCT references	Overall conclusions
Wounds healing by primary intention	Webster <i>et al</i> (2014) ²⁶	0	In closed surgical wounds, the evidence for the effects of NPWT for reducing surgical site infection (SSI) and wound dehiscence remains unclear, as does the effect of NPWT on time to complete healing.
Split thickness skin grafts	Yin <i>et al</i> (2018) ³⁶ ; Azzopardi <i>et al</i> (2013) ²⁷	0	The most recent review (Yin <i>et al</i> , 2018) concluded that compared with conventional therapy, NPWT significantly increased the rate of graft take and reduced the rate of reoperation when applied to cover the wound bed with split thickness skin graft; but no impact on wound infection was found. An older review (Azzopardi <i>et al</i> , 2013) also reported positive results, stating that NPWT may impart considerable advantage over traditional dressings in quality and quantity of take. However, in both reviews, the authors note the lack of high-quality RCTs.
Skin flaps	Yu <i>et al</i> (2017) ³⁸	0	One review, for which the full text was not obtainable and so not critically appraised, concluded that NPWT may facilitate flap transfer and help to rescue flaps threatened by infection and venous congestion.
Cesarean wounds	Yu <i>et al</i> (2018) ³⁷ ; Smid <i>et al</i> (2017) ³⁵	Hyldig <i>et al</i> (2018) ⁴⁰ ; Wihbey <i>et al</i> (2018) ⁴¹	Two reviews were identified that evaluated the prophylactic use of NPWT after caesarean sections. They included largely the same evidence base, although analysed the data differently. Yu <i>et al</i> concluded that studies were heterogeneous, but suggested a reduction in SSI and overall wound complications. The conclusions from Smid <i>et al</i> were less positive, with the authors stating that the current evidence does not support the prophylactic use of NPWT after caesarean sections in obese women. Two additional RCTs were identified, but the results of these were inconsistent, making any robust conclusions impossible.

<p>Closed incision wounds</p> <p>NB The reviews/RCTs in this category evaluated the prophylactic use of NPWT for closed surgical incisions (or talked about the use of incisional NPWT).</p>	<p>Cahill <i>et al</i> (2018)²⁹; Strugala <i>et al</i> (2017)³⁹; Hyldig <i>et al</i> (2016)³⁰; Scalise <i>et al</i> (2016)³³; Sandy-Hodgetts <i>et al</i> (2015)³²; Semsarzadeh <i>et al</i> (2015)³⁴; Ingargiola <i>et al</i> (2013)³¹; CADTH (2013)²⁸</p>	<p>Crist <i>et al</i> (2018)⁴²; Engelhardt <i>et al</i> (2018)⁴³; Gombert <i>et al</i> (2018)⁴⁴; Kwon <i>et al</i> (2018)⁴⁵; Lee <i>et al</i> (2017)⁴⁶; Pleger <i>et al</i> (2018)⁴⁷; Suh <i>et al</i> (2016)⁴⁸</p>	<p>Seven reviews evaluated the prophylactic use of NPWT for closed surgical incisions. The most recent review (Cahill <i>et al</i>) reported a decrease in perineal wound complications after abdominoperineal resection. The next two most recent reviews (Hyldig <i>et al</i> and Scalise <i>et al</i>) reported similar conclusions: compared to standard care, NPWT was associated with reductions in wound infection and seroma formation, but not in dehiscence. However, the review authors also note weaknesses in the evidence base, meaning definitive conclusions are not possible. The four older reviews are generally in agreement.</p> <p>Seven additional RCTs were identified, six of these relating to the use of NPWT on closed wounds after vascular surgery. The results of these were inconsistent. Some reported reduced rates of infection with NPWT, but the differences were not statistically significant. Two studies report statistically significant reductions in wound complications and re-operations/revisions.</p>
<p>Prophylactic use in other closed surgical wounds</p>	<p>De Vries <i>et al</i> (2016)⁴⁹; Swanson <i>et al</i> (2016)⁵⁰</p>	<p>O'Leary <i>et al</i> (2017)⁵¹; Shen <i>et al</i> (2017)⁵²; Manoharan <i>et al</i> (2016)⁵³</p>	<p>One review evaluated the prophylactic use of NPWT in clean and contaminated surgery generally (De Vries <i>et al</i>) and another considered its use after ventral hernia repair only (Swanson <i>et al</i>). There was overlap in the included studies, although De Vries <i>et al</i> had a broader inclusion criteria. De Vries <i>et al</i> reported that summary estimates showed a benefit of NPWT over conventional dressings in reducing SSIs, although caution that their confidence in this estimate is low and that more research is required. Swanson <i>et al</i> also reported a reduction in SSIs, and the need for more high-quality research. Three additional RCTs were identified, the first included 50 patients, and compared prophylactic NPWT with standard dressings on postoperative SSI rates in closed laparotomy wounds (no statistically significant difference). The second RCT included 256 patients who underwent open resection of intra-abdominal neoplasms, and the authors reported no difference in superficial or deep SSI rates between the standard dressing and NPWT group. The last RCT included 21 patients having bilateral knee arthroplasty, and the authors reported no benefit in wound healing, but improvements in wound leakage and wound protection in the NPWT group (compared to conventional dry dressings).</p>

Mixed wounds healing by primary intention

A Cochrane review (Webster *et al*, 2014) included nine RCTs, encompassing 785 participants: three involved skin grafts; four included orthopaedic patients; two included general surgery and trauma patients²⁶. Eight of the RCTs compared NPWT with standard dressings (in two of these studies, 'home-made' NPWT devices were used), and one compared 'home-made' NPWT with a commercially available device. All trials were rated as having an unclear or high risk of bias on one or more of the quality indicators assessed. A summary of the main results for the comparison of NPWT to standard dressings is given below:

- Surgical site infection (SSI; four RCTs, 498 participants): In three studies, the individual was the unit of randomisation, and pooled results suggested no difference between NPWT and standard dressings in the rate of SSI (RR 1.02; 95% CI 0.41 to 2.54; $p=0.97$). In the remaining study randomisation was done by wound, and this reported fewer SSIs in the NPWT group (9.7% versus 18.9%; RR 0.52; 95% CI 0.28 to 0.96; $p=0.04$).
- Dehiscence (two studies, 203 participants): two studies, not combined in a meta-analysis, reported no significant between-group differences for dehiscence outcome.
- Secondary outcomes: there were no significant between-group differences in the re-operation (in incisional wounds); seroma/haematoma; length of hospital stay; time to complete healing; or failed skin grafts.
- In two trials (131 participants) assessing re-operation rates among skin graft patients, pooling of data favoured NPWT over other dressings (RR 0.42; 95% CI 0.19 to 0.92; $p=0.03$). In both these trials, 'home-made' NPWT dressings were used.
- One trial in orthopaedic patients was stopped early because of a high incidence of fracture blisters in the NPWT group compared with the standard dressing group (62.5% versus 8.3%; RR 7.5; 95% CI 2.43 to 23.14).

The authors concluded that in closed surgical wounds, the evidence for the effects of NPWT on SSI and wound dehiscence remains unclear, as does the effect of NPWT on time to complete healing. They also highlight the high incidence of blisters occurring following orthopaedic surgery suggests that the therapy should be limited until safety in this patient group is established.

Split-thickness skin grafts

Two systematic reviews were identified that evaluated the use of NPWT in split-thickness skin grafts^{27, 36}.

The first review, by Yin *et al* (2018)³⁶, was a reasonable quality systematic review and meta-analysis which aimed to compare the clinical outcomes of NPWT versus conventional therapy on split-thickness skin after grafting surgery. It included five cohort studies and

seven RCTs, encompassing 653 patients. Two of the RCTs were included in the review by Webster *et al* (2014) described previously. The authors state that the quality of the included studies was good, although acknowledge that cohort studies are likely to be more prone to bias compared with well conducted RCTs. However, one of the included 'RCTs' was excluded from the Cochrane review (Webster *et al* 2014) as it was not a randomised trial. Therefore, it appears that the quality assessment of the included studies has possibly been over-generous. The authors reported that patients treated with NPWT had a significantly higher rate of graft take compared to those treated with conventional therapy (MD 7.02; 95% CI 3.74 to 10.31, $p < 0.0001$). However, there was statistical heterogeneity between these studies ($I^2 = 68\%$). Sensitivity analyses showed that this heterogeneity was resolved by excluding one study (though the authors do not report a new mean difference and confidence interval). They also reported that NPWT was associated with a reduction in re-operation rate (RR 0.28; 95% CI 0.14 to 0.55; $p = 0.0002$; $I^2 = 0\%$). No significant between-group difference for wound infection was reported. The authors concluded that compared with conventional therapy, NPWT significantly increases the rate of graft take and reduces the rate of reoperation when applied to cover the wound bed with split-thickness skin grafts; but no impact on wound infection was found.

The second review (Azzopardi *et al*, 2013) stated that: "this systematic review suggests that TNP [*topic negative pressure*] may impart a considerable advantage to split skin grafting over traditional dressings in quality and quantity of take. The current best-evidence recommendations provide a robust rationale for the continued use of TNP to STSG [*split thickness skin grafts*] especially in complex, large, exuding, irregularly contoured wounds...well-conducted randomized clinical controlled trials in this area are sparse..."²⁷.

Skin flaps

A systematic review (Yu *et al*, 2017) concluded that "NPWT may facilitate flap transfer with few side effects and help to rescue flaps threatened by infection and venous congestion with a high salvage rate. Further studies are needed to test the safety of NPWT application on flaps with arterial compromise"³⁸. This was based on 16 articles. The full text of this review was not obtainable, and so a full description of results and critical appraisal is not possible.

Prophylactic use after caesarean sections

Two systematic reviews were identified on the prophylactic use of NPWT after caesarean sections^{35, 37}. The results suggested that there is a lack of definitive evidence surrounding the prophylactic use of NPWT after caesarean sections.

The first (Yu *et al*, 2018) systematic review with meta-analyses included nine studies (six RCTs and three cohort studies)³⁷. The authors reported that compared with standard wound dressings, prophylactic NPWT was associated with a significantly lower risk of SSI (seven studies; RR 0.45; 95% CI 0.31 to 0.66). While there was no evidence of statistical heterogeneity ($I^2 = 9.9\%$), the authors reported clinical heterogeneity between the studies

(for example, with regards to the devices used and the people included). In addition, the authors reported that prophylactic NPWT was associated with a statistically significant reduction in wound complications (nine studies; RR 0.68; 95% CI 0.49 to 0.94). No significant between group differences were found for wound dehiscence (five studies), seroma (two studies), endometritis (three studies), or hospital readmission rates (two studies). On the whole, this review appears to have been well conducted, however the authors acknowledge that their findings “carry forward the limitations of the primary studies”. In addition the results from RCTs and cohorts have been pooled together in meta-analyses, perhaps leading to over-estimated effects of NPWT. The authors concluded that the studies on the effectiveness of prophylactic NPWT are heterogeneous, “but suggest a reduction in surgical site infection and overall wound complications”. They also note that there is a need for larger trials before definitive conclusions are possible.

The second systematic review compared the prophylactic use of NPWT with standard dressings after caesarean delivery in obese women (Smid *et al*, 2017)³⁵. It included largely the same evidence base as Yu *et al* (2018) but their conclusions were less positive, with the authors stating that the currently “available evidence does not support negative pressure wound therapy use among obese women for caesarean wound complication prevention”. The less positive conclusion may reflect differences in how the data was analysed. Smid *et al* reported on one composite primary outcome of wound complications, including wound or surgical site infection, cellulitis, seroma, hematoma, wound disruption or dehiscence. In addition, the meta-analysis was limited to RCT data and was presented alongside a fuller narrative review of the results of the RCTs and cohort studies. In the meta-analysis, there was no difference in primary composite outcome among those women with NPWT (16.8%) compared with those who had standard dressings (17.8%) (RR 0.97, 95% CI 0.63 to 1.49; $I^2=17\%$).

Our literature search identified a further two RCTs on the prophylactic use of NPWT in obese women after caesarean delivery. The first, by Hyldig *et al* (2018), aimed to evaluate the impact on SSIs of prophylactic NPWT compared with standard postoperative dressings in this patient group (n=876)⁴⁰. The authors reported that SSI occurred in 4.6% of women treated with incisional NPWT (iNPWT) compared with 9.2% treated with a standard dressing (RR 0.50; 95% CI 0.30 to 0.84; $P=0.007$; number needed to treat 22). The review authors concluded that prophylactic use of iNPWT reduced the risk of SSI in obese women giving birth by caesarean section. Conversely, the authors of the second RCT concluded that until the results of larger RCTs were published, they recommend against the use of prophylactic NPWT after caesarean delivery (Wihbey *et al*, 2018)⁴¹. This RCT (n=166) aimed to compare the occurrence of superficial SSIs in obese women using prophylactic NPWT with standard dressings after caesarean delivery. The trial was stopped early due to low enrolment. In the included participants, no difference was observed in superficial SSI between the groups.

Closed incision wounds

Seven reviews evaluated the prophylactic use of NPWT for closed surgical incisions (or talked about the use of incisional NPWT). The main conclusions from each review are summarised below:

- Cahill *et al* (2018)²⁹: This systematic review aimed to evaluate the use of incisional NPWT (iNPWT) on perineal wounds after abdominoperineal resection, and to determine the effect on perineal complications. Five articles were included, encompassing 169 patients. The authors reported a decrease in wound complications with NPWT compared with control groups (including surgical site infection rates) although meta-analyses were not done due to heterogeneity between the studies. The authors also note that no prospective or randomised studies were identified, and that there were methodological limitations in the included studies (three retrospective cohorts, one case series and one video case report).
- Strugala *et al* (2017)³⁹: This review included ten RCTs and six observational studies, and focused on single-use NPWT devices compared with standard care in closed surgical incisions. The authors do not discuss the quality of the included studies. They conclude that there was a significant reduction in surgical site infection, wound dehiscence, and length of hospital stay in the people treated with single-use NPWT.
- Hyldig *et al* (2016)³⁰: Similar to the previous systematic reviews, Hyldig *et al* (2016) concluded that in closed surgical incisions, compared with standard postoperative dressings, NPWT was associated with a significant reduction in wound infection rate compared with standard care (RR 0.54, 95% CI 0.33 to 0.89). The authors also reported a reduction in seroma formation (RR 0.48, 95% CI 0.27 to 0.84) but no statistically significant reduction in dehiscence. However, the authors note that there was considerable heterogeneity between the studies, and concluded that the evidence base was at present insufficient to make general recommendations.
- Scalise *et al* (2016)³³: “The literature shows a decrease in the incidence of infection, sero-haematoma formation and on the re-operation rates when using iNPWT. Lower level of evidence was found on dehiscence, decreased in some studies, and was inconsistent to make a conclusion”.
- Sandy-Hodgetts *et al* (2015)³²: “Given the small number of studies, mostly retrospective comparative cohort in design, no definitive conclusions can be reached as to the effectiveness of the use of negative pressure wound therapy in the prevention of surgical wound complications. However, there was a demonstrated association between the use of negative pressure wound therapy and reduction in surgical site infection.”
- Semsarzadeh *et al* (2015)³⁴: “The results of this meta-analysis suggest that closed incision negative-pressure therapy is a potentially effective method for reducing surgical-site infections. It also appears that closed incision negative-pressure therapy may be associated with a decreased incidence of dehiscence, but the published data available were too heterogeneous to perform meta-analysis.”
- Ingargiola *et al* (2013)³¹: “This systematic review shows possible evidence of a decrease in the incidence of infection with application of iNPWT. Looking at other variables such as dehiscence, seroma, hematoma, and skin necrosis show no

consistent data and suggest further studies in order for proper recommendations for iNPWT”.

- CADTH (2013)²⁸: “...The results of the studies were mixed. Eleven studies reported positive results with NPWT; no difference between NPWT and traditional dressings were found in two studies; and the authors of the three systematic reviews determined there was not enough information available to make a recommendation for or against NPWT”.

An additional seven RCTs not included in the systematic reviews on the use of NPWT for closed surgical incisions were identified. One aimed to establish whether iNPWT decreased the risk of infection in patients undergoing open reduction internal fixation (ORIF) for acetabular fractures (n=66)⁴². The authors concluded that there was a need for larger trials to establish whether iNPWT use reduced infections in this patient group. The remaining six RCTs related to the use of NPWT on closed incisions after vascular surgery⁴³⁻⁴⁸. These are summarised below:

- Engelhardt *et al* (2018)⁴³: This RCT included 132 participants scheduled for vascular surgery with a longitudinal femoral cut-down. The aim was to evaluate the impact of closed-incision NPWT (ciNPWT) on wound infections after vascular surgery compared with conventional dressings. The overall infection rates were 14% (9/64) in the closed-incision NPWT group compared with 28% (19/68) in the standard dressing group (p=0.055). The authors concluded that: “While the experiences with the ciNPWT device were encouraging, the study fails to provide evidence of the efficacy of the device to reduce groin wound infections after vascular surgery”.
- Gombert *et al* (2018)⁴⁴: Like Engelhardt *et al*, this study aimed to assess the effect of closed-incision NPWT after groin incisions for vascular surgery, compared with standard wound dressings (n=204). The authors reported that the control group experienced more frequent surgical site infections compared with the NPWT group, though this difference did not reach statistical significance (33.3% versus 13.2%, absolute difference -20.1%; 95% CI -31.9% to 8.2%).
- Kwon *et al* (2018)⁴⁵: This RCT (n=119) evaluated the effect of NPWT on the healing of elective vascular surgery groin incisions compared with standard dressings (gauze) during a 30-day period. Wounds considered to be at ‘high risk’ of wound complications were included, and this was based on factors such as BMI, poor nutrition, and prosthetic graft. Major wound complications were reported in 25% of the control group, and 8.5% of the NPWT group (p<0.001). Readmission (16.7% versus 6.8%; p<0.04) and re-operation (18.3% versus 8.5%; p<0.05) rates were also significantly lower in the NPWT group, but there was no statistically significant difference length of stay. The authors concluded that NPWT reduces major wound complication, reoperation and readmission rates for patients at high risk of groin wound complications.

- Lee *et al* (2017)⁴⁶: This study aimed to assess the effect of NPWT on SSI in closed groin wounds after lower extremity revascularisation in patients at high risk of SSI. The authors report that this study is likely underpowered (n=102). There was no statistically significant difference in the primary outcome of 30-day SSI, which was 11% in the NPWT group versus 19% in the standard dressing group (p=0.24).
- Pleger *et al* (2018)⁴⁷: This RCT aimed to investigate the effectiveness of ciNPWT compared with conventional therapy (adhesive plaster) on groin incisions after vascular surgery. It included 100 patients with 129 groin incisions. The authors reported a significant reduction in the NPWT group for wound complications (p<0.0005) and revision surgeries (p=0.022) until 30 days postoperatively.
- Suh *et al* (2016)⁴⁸: This study evaluated the effects of NPWT on primary closed wounds after circumflex iliac artery perforator flap harvest. The authors concluded that incisional NPWT had a positive effect over primary closed surgical defects by significantly reducing the amount of fluid collected by closed suction drains, allowing earlier removal of drains and enhancing perfusion of the repaired skin.

Prophylactic use in other closed surgical wounds

In the previous section, the reviews/RCTs evaluated the prophylactic use of NPWT for closed surgical incisions generally or talked about the use of incisional NPWT. The studies included in this section talk about specific surgical procedures and describe the intervention as NPWT rather than incisional NPWT.

Two reviews were identified: One evaluated the prophylactic use of NPWT in clean and contaminated surgery generally (De Vries *et al*)⁴⁹ and another considered its use after ventral hernia repair only (Swanson *et al*)⁵⁰.

The systematic review with meta-analyses by De Vries *et al* (2016) compared the prophylactic use of NPWT with conventional dressings in clean and contaminated surgery. It included 19 articles describing 21 studies (six RCTs and 15 observational). Nine studies were on abdominal surgery (four involved ventral hernia repair procedures), six were in orthopaedic or trauma surgery, two were in cardiac surgery, two were in vascular surgery, and one included both abdominal and breast surgery. Summary estimates showed a significant benefit of prophylactic NPWT over conventional wound dressings in reducing SSIs in both the RCTs (OR 0.56, 95% CI 0.32 to 0.96, p=0.04) and observational studies (OR 0.30, 95% CI 0.22 to 0.42 p<0.00001). In stratified analyses, these results were consistent in both clean and clean-contaminated procedures and in different types of surgery, however results were no longer significant for orthopaedic/trauma surgery. However, the authors caution that confidence in their estimate of effect was low and that further research was required.

The systematic review with meta-analysis by Swanson *et al* (2016) included five retrospective cohort studies, encompassing 477 patients, and evaluated whether prophylactic NPWT following ventral hernia repair prevented wound complications and hernia recurrence, compared with conventional dressings. Three of these studies were

included in the review by De Vries *et al* (2016). In line with the conclusions by De Vries *et al*, the authors reported that in patients undergoing ventral hernia repair, NPWT decreased rates of SSI compared with conventional dressings (OR 0.33, 95% CI 0.20 to 0.55, $p < 0.0001$). The authors also reported decreased rates of wound dehiscence (OR 0.21, 95% CI 0.08 to 0.55, $p = 0.001$) and ventral hernia recurrence (OR 0.24, 95% CI 0.08 to 0.75, $p = 0.01$). There was no between group difference in incidence of seroma formation (OR 0.59, 95% CI 0.27 to 1.27, $p = 0.18$).

Our literature search identified three additional RCTs relating to the prophylactic use of NPWT on surgical incisions.

- O’Leary *et al* (2017)⁵¹: This RCT ($n = 50$) aimed to investigate the effect of prophylactic NPWT compared with standard dressings on postoperative SSI rates in closed laparotomy wounds. The primary outcome was SSI incidence at 30 days postoperatively. The authors report that the incidence of SSI at 30 days was lower in the NPWT group, but this difference is not statistically significant (8.3% versus 32%; $p = 0.074$). In addition, the analysis was per-protocol rather than intention to treat which may bias the results in favour of the NPWT group.
- Shen *et al* (2017)⁵²: This well-reported RCT included 256 patients who underwent open resection of intra-abdominal neoplasms (gastrointestinal, pancreas or peritoneal surface malignancy). They were randomised to receive NPWT or standard surgical dressings applied to the incision from postoperative days one through to four. Primary outcomes of combined incisional (superficial and deep) SSI rates were assessed up to 30 days after surgery. The authors reported that there were no significant differences in superficial SSIs (12.8% versus 12.9%; $p > 0.99$) or deep SSIs (3% versus 3%; $p > 0.99$) rates between the standard dressing and NPWT groups. There were no significant differences when the analyses were stratified by type of surgery. Based on these results the authors concluded that NPWT “cannot be recommended as a therapeutic intervention to decrease infectious complications in these patient populations”. The authors note that there are ongoing trials in this area, and with more prospective studies “a clearer picture on the role of NPWT for closed laparotomy incisions should emerge”.
- Manoharan *et al* (2016)⁵³: This study included 21 patients having bilateral knee arthroplasty, and either side was randomised to NPWT or conventional dry dressings. The aim of the study was to assess the effects of NPWT on quality of life, wound complications, and cost. The authors reported no benefit in wound healing or cost with NPWT post knee arthroplasty. However, statistically significant improvements in scores of wound leakage (0.14 versus 0.39, $p = 0.019$) and wound protection (0.16 versus 0.33, $p = 0.001$) were reported in the NPWT group.

Current position in light of new evidence

The most comprehensive review for this patient group (skin grafts and surgical wounds healing by primary intention) concluded that: “In closed surgical wounds, the evidence for the effects of NPWT for reducing surgical site infection (SSI) and wound dehiscence remains unclear, as does the effect of NPWT on time to complete healing”²⁶.

A small number of reviews reported positive results with NPWT (for example, increased graft take and reduced rate of reoperation with split thickness skin grafts; and reduced incidence of wound infection in closed incision wounds). However, several of the reviews consistently reported the need for good quality trials, and so confidence in these positive findings is low.

Additional RCTs were identified but the results from these are inconsistent and trial authors’ often reported the need for additional well-conducted RCTs before definitive conclusions were possible. One well-reported RCT found no significant differences in superficial SSIs or deep SSIs between NPWT and standard dressings in patients who underwent open resection for intra-abdominal neoplasms.

Surgical wounds: wounds healing by secondary intention

Main findings from 2010 HTA

The HTA from 2010 did not include a section on surgical wounds healing by secondary intention.

Literature published after 2010 HTA

A good quality Cochrane review from 2015 assessed the effects of NPWT on surgical wounds healing by secondary intention (excluding open abdomen wounds) in any care setting (Dumville *et al*, 2015)⁵⁴. The review included two RCTs, encompassing 69 patients. One compared NPWT with an alginate dressing in the treatment of open, infected groin wounds; and one compared NPWT with a silicone dressings in the treatment of excised pilonidal sinus. The authors of the review stated that the trials reported limited outcome data for healing, adverse events and resource use. The first study (n=20) suggested that time to healing was shorter for participants in the NPWT group (57 days) compared to the alginate group (104 days) and reported no difference for number of amputations or number of deaths. The second study reported shorter median time of healing in the NPWT group (84 days) compared to the silicone dressing group (93 days). However, the review authors concluded that the potential benefits and harms of using this treatment for this wound type remain largely uncertain.

Current position in light of new evidence

While the evidence suggests that there may be a benefit of using NPWT on wounds healing by secondary intention, it is too weak to definitively support or refute its use in this patient group.

Surgical wounds: sternal wound infections

Main findings from 2010 HTA

The HTA from 2010 stated that no RCTs were identified on the use of NPWT for sternal wound infections that developed after cardiothoracic surgery. Some non-randomised trials and retrospective reviews were included, which suggested that NPWT may be associated with reduced mortality. However the overall evidence to endorse NPWT in the routine management of deep sternal wound infections after cardiac surgery was too weak to base any firm conclusions.

Literature published after 2010 HTA

Two systematic reviews from 2013 were identified which evaluated the use of NPWT on patients with sternal wound infections after cardiothoracic surgery^{55, 56}.

The first, by Falagas *et al* (2013), included 22 retrospective cohorts encompassing 2,467 patients⁵⁵. The authors combined the data in meta-analyses and reported that patients treated with NPWT had lower mortality compared with patients treated without NPWT (RR=0.40, 95% CI 0.28 to 0.57; $I^2=16\%$). They also reported that NPWT was associated with fewer infection recurrences (RR=0.34, 95% CI 0.19 to 0.59; $I^2=48\%$), but no significant difference in length of hospital stay (RR=-2.25, 95% CI -7.52 to 3.02; $I^2=82\%$). The authors concluded that “the currently available data from retrospective cohort studies suggest that the use of VAC therapy [NPWT] was associated with lower mortality than non-VAC therapy for the treatment of patients with deep sternal wound infections after cardiovascular surgery”. However, they also note that the retrospective nature of the included studies means that the results need to be treated with caution and that good-quality RCTs are required.

The second systematic review, by Pan *et al* (2013), aimed to compare NPWT to conventional therapy (standard debridement and drainage therapy) in the treatment of deep surgical site infections, particularly post-sternotomy infections⁵⁶. The authors included 12 ‘low quality’ cohort studies, which together suggest that NPWT might be more effective than standard therapy in the cure of post-sternotomy mediastinitis and deep-sternal wound infections. However, in line with Falagas *et al*, the authors note the need for good quality RCTs, and the “strong need for actual investigation rather than just observation”.

Current position in light of new evidence

There is still a need for good quality RCTs. The currently available evidence on the use of NPWT in sternal wound infections after cardiothoracic surgery is weak, but suggests that outcomes (including mortality) may be better with NPWT compared to standard therapy.

Surgical wounds: other

Three other systematic reviews were identified, relating to other types of surgical wounds. The main conclusions from these reviews are summarised below:

- Ousey *et al* (2013)⁵⁷: The review evaluated the effectiveness of NPWT in patients with a spinal wound. The authors identified ten retrospective studies and four case studies, and concluded that “larger prospective RCTs of NPWT are needed to support the current evidence that it is effective in treating spinal wound complications”.
- Misky *et al* (2016)⁵⁸: The review included ten studies (151 patients) evaluating the use of NPWT for enterocutaneous fistula⁵⁸. The authors described the current evidence as ‘of low level’ and ‘characterised by heterogeneity’, therefore highlight the need for further studies to establish any benefit over standard surgery or conservative therapy.
- Efthymios *et al* (2014): The full text of this review was not obtainable, but based on the abstract it evaluated the use of NPWT in the healing of breast tissues. It included 20 studies (four cohort studies, one case series and 15 case reports; together encompassing 154 patients), and most lesions were secondary to plastic surgery (n=107), or other surgery (n=40). Like most reviews on NPWT, the authors concluded that the evidence base is weak, that NPWT might be useful in the healing of complicated breast wounds, and that more research is required.

In addition, a search for RCTs published since the systematic reviews identified a further study that did not fit under the other chapter headings:

- Johnson *et al* (2018)⁵⁹: This small RCT included 10 participants (14 wounds) who underwent an extremity fasciotomy following trauma. The aim of the study was to examine the effectiveness of the ‘shoelace’ technique compared with NPWT on achieving primary skin closure of fasciotomy wounds. The authors reported that after interim analyses, the study was closed early with all five wounds treated with the shoelace technique closed primarily, compared with only one out of nine wounds treated with NPWT. The authors concluded that these results suggested that a simple shoelace technique is more successful than NPWT for achieving same hospital stay skin closure.

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