

## Original Investigation

# Systemic Review and Meta-analysis of Randomized Clinical Trials Comparing Primary vs Delayed Primary Skin Closure in Contaminated and Dirty Abdominal Incisions

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**IMPORTANCE** Surgical site infection remains a major challenge in surgery. Delayed primary closure of dirty wounds is widely practiced in war surgery; we present a meta-analysis of evidence to help guide application of the technique in wider context.

**OBJECTIVE** To determine using meta-analysis whether delayed primary skin closure (DPC) of contaminated and dirty abdominal incisions reduces the rate of surgical site infection (SSI) compared with primary skin closure (PC).

**DATA SOURCES** A systematic review of the literature published after 1990 was conducted of the Medline, PubMed, Current Controlled Trials, and Cochrane databases. The last search was performed on October 6, 2012. No language restrictions were applied.

**STUDY SELECTION** Randomized clinical trials comparing PC vs DPC were included.

**DATA EXTRACTION AND SYNTHESIS** Two of us independently selected studies based on quality assessment using the Cochrane Collaboration tool for assessing risk of bias in randomized trials. Data were pooled using fixed- and random-effects models.

**MAIN OUTCOME AND MEASURE** Rate of SSI, as defined by the individual study.

**RESULTS** The final analysis included 8 studies randomizing 623 patients with contaminated or dirty abdominal wounds to either DPC or PC. The most common diagnosis was appendicitis (77.4%), followed by perforated abdominal viscus (11.5%), ileostomy closure (6.5%), trauma (2.7%), and intra-abdominal abscess/other peritonitis (1.9%). The time to first review for DPC was provided at between 2 and 5 days postoperatively. All studies were found to be at high risk of bias, with marked deficiencies in study design and outcome assessment. When SSI was assessed across all studies using a fixed-effect model, DPC significantly reduced the chance of SSI (odds ratio, 0.65; 95% CI, 0.40-0.93;  $P = .02$ ). However, heterogeneity was high (72%), and using a random-effects model, the effect was no longer significant (odds ratio, 0.65; 95% CI, 0.25-1.64;  $P = .36$ ).

**CONCLUSIONS AND RELEVANCE** Delayed primary skin closure may reduce the rate of SSI, but current trials fail to provide definitive evidence because of poor design. Well-designed, large-numbered randomized clinical trials are warranted.

*JAMA Surg.* 2013;148(8):779-786. doi:10.1001/jamasurg.2013.2336  
Published online June 26, 2013.

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**S**urgical site infection (SSI) following abdominal surgery is common. When assessed actively and prospectively, it has been found to affect as many as 45% of patients.<sup>1</sup> Furthermore, without active postdischarge surveillance, up to 79% of SSI will be missed.<sup>2</sup> Surgical site infection confers significant morbidity, with an additional risk of mortality.<sup>3</sup> There are further health care-related costs, through increased hospital stay, repeated surgery, nursing care costs, and drug treatment.<sup>4</sup> Because of these factors, there is international interest in reducing the rate of SSI.

Surgical site infection presents an attractive target for randomized clinical trials (RCTs). There have been several large-scale RCTs assessing the impact of perioperative optimization and intraoperative surgical technique to reduce the rate of SSI.<sup>1,5-8</sup> These studies are limited by the sometimes weak methodological design.<sup>7</sup> Furthermore, some of the measures require extra equipment (with associated logistical and financial costs), and despite their apparent effectiveness, SSI rates remain persistently high.

Delayed primary skin closure (DPC) represents a technique where no specialist equipment is required. It can be used when contaminated or dirty wounds are created, allowing the soft tissues to drain (and preventing accumulation of microorganisms in a confined space) before closing the skin a few days later. It may have a role in reducing SSI not only for civilian practice, but also for austere, military, and developing world practices. The aim of this study was to compare DPC against primary skin closure (PC) to assess its effectiveness at reducing SSI. Because of the potential for selection bias, such a comparison provides the best evidence when limited to RCTs only. Since blinding of surgeons and patients is not possible with this technique, particular attention was paid to other aspects of study design, including adequacy of randomization and blinded outcome assessment at 30 days.

## Methods

### Data Sources and Search Strategy

A systematic search of the OvidSP version of Medline, PubMed version of Medline, the Cochrane Database of Systematic Reviews, Current Controlled Trials, and ClinicalTrials.gov was performed for published RCTs comparing PC and DPC. Only studies published after 1990 were included, and no language restrictions were applied. The search was performed independently by 2 researchers. The search strategies used are presented in eTable 1 in Supplement. MeSH terms were used to search Medline, combining domains of the operation, wound infection, and randomization with the AND function.

A manual search of reference lists in relevant systematic reviews was undertaken to further identify randomized trials of potential interest. Abstracts and conference proceedings were excluded because of the high probability of incomplete data. Citations were collated with EndNote Reference Manager (version X4; Thomson Reuters). The study protocol was registered with the PROSPERO database ([www.crd.york.ac.uk/prospero/](http://www.crd.york.ac.uk/prospero/)). The last search was performed on October 6, 2012.

### Inclusion and Exclusion Criteria

#### Inclusion Criteria

Randomized clinical trials comparing PC vs DPC of the skin layer of contaminated and dirty abdominal surgical incisions were included. Delayed primary wound closure was defined as the planned action to leave the skin edges unopposed (following fascial closure) with a delayed attempt to subsequently oppose the skin edges. Any surgical incision of the abdomen was eligible.

#### Exclusion Criteria

The following exclusion criteria were applied: nonrandomized studies; studies published prior to 1990; studies where the fascia was left open; and studies considering planned healing by secondary intention (where no assessment for delayed closure was planned).

#### Data Extraction

Two of us (A.B. and P.S.) extracted data independently. Discrepancies in outcome extraction were resolved by reexamination until consensus was achieved.

Data extracted on study design included randomization technique, intervention arms, wound contamination as defined by the criteria set by the Centers for Disease Control and Prevention (eTable 2 in Supplement),<sup>9</sup> wound management prior to delayed closure, concomitant antibiotic therapy, time to first assessment for delayed closure, method of delayed closure, definition of wound infection, and method of assessment for wound infection.

Details relating to included patients were number, age, sex, operation indication, and presence of comorbidities.

#### Outcome Measures

The primary outcome assessed for meta-analysis was the rate of SSI, as defined by the individual study. Secondary outcomes recorded were rate of healing by secondary intention (which included superficial wound dehiscence for the PC group); rate of fascial dehiscence; and length of stay.

#### Assessment of Bias

Risk of bias was assessed using the Cochrane Collaboration tool for assessing risk of bias in randomized trials.<sup>10</sup> This tool covers 6 domains: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias. Each domain was scored as a high, low, or unclear risk of bias. Since blinding of the operating surgeon was not feasible, this was not assessed as a source of high bias. To counter this, adequate randomization was considered vital to minimize the risk of bias introduced by lack of blinding. Blinding of the outcome assessor was considered feasible and its absence, a source of high bias. Studies with poor, uncertain, or unclear methods of randomization were considered to be at high risk of bias. Additional prespecified sources of bias were adequacy of complete wound review at 30 days and provision for an accepted definition of SSI, such as that provided by the Centers for Disease Control and Prevention.<sup>11</sup> A prespecified assessment of publication bias was performed by means of a funnel plot.

### Statistical Analysis

Meta-analysis was conducted according to guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-analysis group. The odds ratio (OR) was used as the statistical measure for dichotomous outcomes. The ORs were calculated from the original data and meta-analysis was performed using the Mantel-Haenszel method. The OR represents the odds of an adverse event (such as wound infection) occurring in the experimental group (ie, DPC) vs the control group (ie, PC).  $P < .05$  was considered significant for all analyses.

Between-study heterogeneity was assessed using the  $I^2$  and  $\chi^2$  statistic and funnel plots. Higher values of  $I^2$  and the  $\chi^2$  statistic signified increasing levels of heterogeneity, with  $P < .05$  or an  $I^2$  value exceeding 50% indicating significant heterogeneity.<sup>12</sup> Because of the chance of high heterogeneity due to the likelihood of differing inclusion criteria from individual studies, it was decided a priori to perform both fixed- and random-effects models for all end points.<sup>13</sup> Statistical analysis was performed using Review Manager 5.0 (Nordic Cochrane Centre, Cochrane Collaboration).

### Sensitivity Analysis

Prespecified sensitivity analysis was planned for studies at low risk of bias and wounds for appendectomy only, where they were available.

## Results

### Cohort Demographics

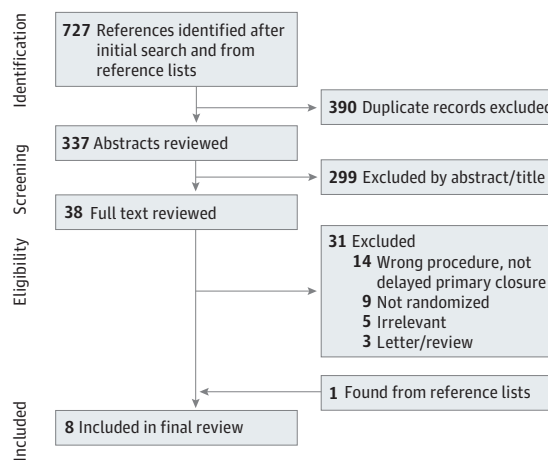
The final analysis included 8 studies randomizing 623 patients to either DPC or PC<sup>14-21</sup> (Figure 1). All studies prespecified contaminated or dirty abdominal wounds as an inclusion criterion (Table 1). Two studies included exclusively pediatric patients,<sup>14,21</sup> and 62.3% of all patients were male (387 of 621 [excludes 2 patients who died with no further data] [eTable 3 in Supplement]). Operation types included appendectomy (77.4%,  $n = 479$ ), laparotomy for perforated abdominal viscus (11.5%,  $n = 71$ ), ileostomy closure (6.5%,  $n = 40$ ), trauma laparotomy (2.7%,  $n = 10$ ), and laparotomy for intra-abdominal sepsis (abscess and/or peritonitis, 1.9%,  $n = 12$ ). Preoperative risk factors for infection as provided by 5 studies are shown in eTable 4 in Supplement. The most common risk factors were smoking ( $n = 51$ ), excess alcohol use ( $n = 34$ ), cardiovascular disease ( $n = 23$ ), and diabetes ( $n = 21$ ).

### Surgical Technique and Skin Closure

Where stated, there were 231 right iliac fossa incisions, 69 midline/paramedian laparotomies, and 40 circumstomal incisions; the remainder of incisions were unstated. Six studies stated the policy use of peritoneal and/or wound irrigation, and 7 studies stipulated use of perioperative antibiotics (eTable 5 in Supplement).

The methods used to pack the wound during initial DPC were provided by 6 studies and are shown in Table 2. The first review for definitive wound closure was provided at between

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analysis Flowchart of Included Studies



2 and 5 days. Six studies provided details of the method of DPC, including 3 studies that used adhesive skin strips and 3 using skin sutures.

### Risk of Bias

Risk of bias was assessed as being high in all studies (eTable 6 in Supplement). Adequate details on randomization were only provided by 2 studies<sup>14,20</sup>; 4 further studies randomized based on hospital number, date of admission, or alternate admission<sup>14,15,19,21</sup>; and 2 provided no details of randomization.<sup>16,17</sup> All studies were at high risk of allocation bias. Six studies were at risk of incomplete follow-up and selective reporting because of a lack of details on losses to follow-up, selective clinical review at 2 weeks only, and reliance on patient-reported adverse events only. No study provided detail of blinding of outcome assessors. Two studies provided a definition of SSI in keeping with widely accepted criteria,<sup>16,17</sup> and only 1 study provided no definition; the remainder relied on the authors' own definitions (Table 2).

Funnel plot analysis showed a wide distribution around the mean for all studies and for appendicitis only studies; an asymmetrical distribution of appendicitis only studies indicated potential publication bias.

### Primary Outcome

When SSI was assessed in all studies using a fixed-effects model, DPC significantly reduced the chance of SSI (OR, 0.61;  $P = .02$ ). However, heterogeneity was high (72%), and using a random-effects model, the effect was no longer significant (Figure 2). For appendicitis only studies, the effect was not significant in either model (Table 3).

### Secondary Outcomes

Pooled effects for the secondary outcomes are shown in Table 3. Length of stay as assessed by all studies was significantly increased with DPC when assessed by a fixed-effects model, but heterogeneity was again high (98%) and a random-effects

Table 1. Demographics of Included Studies

Source, Year	Location	No. Randomized	Inclusion Criteria		Age, y, Mean (SD) [Range]	
			CDC Wound Contamination	Minimum Age, y	DPC	PC
Chiang et al, <sup>15</sup> 2012	Taitung, Taiwan	70	Dirty (perforated appendicitis)	Any	38.2 (15.9)	37.5 (18.3)
Chatwiriyaaroen, <sup>14</sup> 2002	Surin, Thailand	44	Dirty (perforated appendicitis)	<15	Whole group: 9.86 [4-15]	
Cohn et al, <sup>16</sup> 2001	Miami, Florida	51	Dirty (preexisting infection, perforated viscera, traumatic wound with viscus injury >4 h old)	>16	46.3 (20.1)	45.3 (14.9)
Duttaroy et al, <sup>17</sup> 2009	Baroda, India	81	Dirty (preexisting infection, perforated viscera, traumatic wound with viscus injury >4 h old)	Any	34.5 (16.8)	38.2 (17.21)
Khan et al, <sup>18</sup> 2012	Karachi, Pakistan	100	Contaminated/dirty (grossly inflamed, perforated, or gangrenous)	15	31.4 (11.1)	35.3 (14.6)
Lahat et al, <sup>19</sup> 2005	Tel Aviv, Israel	40	Dirty (closure of loop ileostomy)	18	45.5 [18-80]	47.5 [21-73]
McGreal et al, <sup>20</sup> 2002	Cork, Ireland	174	Contaminated/dirty (definitive acute appendicitis diagnosed surgically)	Any	20.5 [6-48]	23 [2-56]
Tsang et al, <sup>21</sup> 1992	Hong Kong	53	Dirty (perforated or gangrenous appendicitis)	Pediatric only	8.4 [4-11.5]	6.5 [2.0-11.0]

Abbreviations: CDC, Centers for Disease Control and Prevention; DPC, delayed primary closure; PC, primary closure.

Table 2. Treatment Arms And Outcome Assessment

Source	DPC	PC	Time to Review for Closure, d	Criteria to Continue DPC	Method of DPC	Definition of Wound Infection	Who Performed Wound Review?	Treatment of Infected Wounds
Chiang et al <sup>15</sup>	Povidone-iodine (0.25%)-soaked gauze	Interrupted skin sutures	5	No wound infection	Repaired under local anesthetic in theater on day 5	Gross purulent discharge with or without positive culture result	Unclear	Opened and packed
Chatwiriyaaroen <sup>14</sup>	Betadine gauze	Unclear	5	Unclear	Until suitable for suture	Purulent discharge or material or surrounding cellulitis	Unclear	Reopened and dressed with later suturing
Cohn et al <sup>16</sup>	Saline-soaked gauze	Staples	3	Pristine wound/no drainage	Adhesive strips on day 4	CDC criteria	1 of 3 Surgical attending physicians	Opened and packed
Duttaroy et al <sup>17</sup>	Saline-soaked gauze	Interrupted skin sutures	2	No excessive purulent discharge	Interrupted skin sutures day 3	CDC criteria	Senior surgeons of the operating team	Opened and packed
Khan et al <sup>18</sup>	Unclear	Unclear	3-5	Unclear	Unclear	Not stated	Unclear	Unclear
Lahat et al <sup>19</sup>	Saline dressing	Skin staples	3	Pristine and no drainage	Nylon sutures day 4	Purulent drainage	1 of 3 Colorectal surgeons	Opened
McGreal et al <sup>20</sup>	Povidone-iodine (1%)-soaked wick	Subcuticular suture	4	Unclear	Steri-Strips on day 4	Cellulitis, culture-positive discharge, purulent discharge, wound abscess requiring I&D	Investigating team	Wound abscesses incised and drained; other wound infections unclear
Tsang et al <sup>21</sup>	Saline dressing	Interrupted skin sutures	4	None	Steri-Strips on day 4	Gross purulent discharge with or without positive culture result	Unclear	Unclear

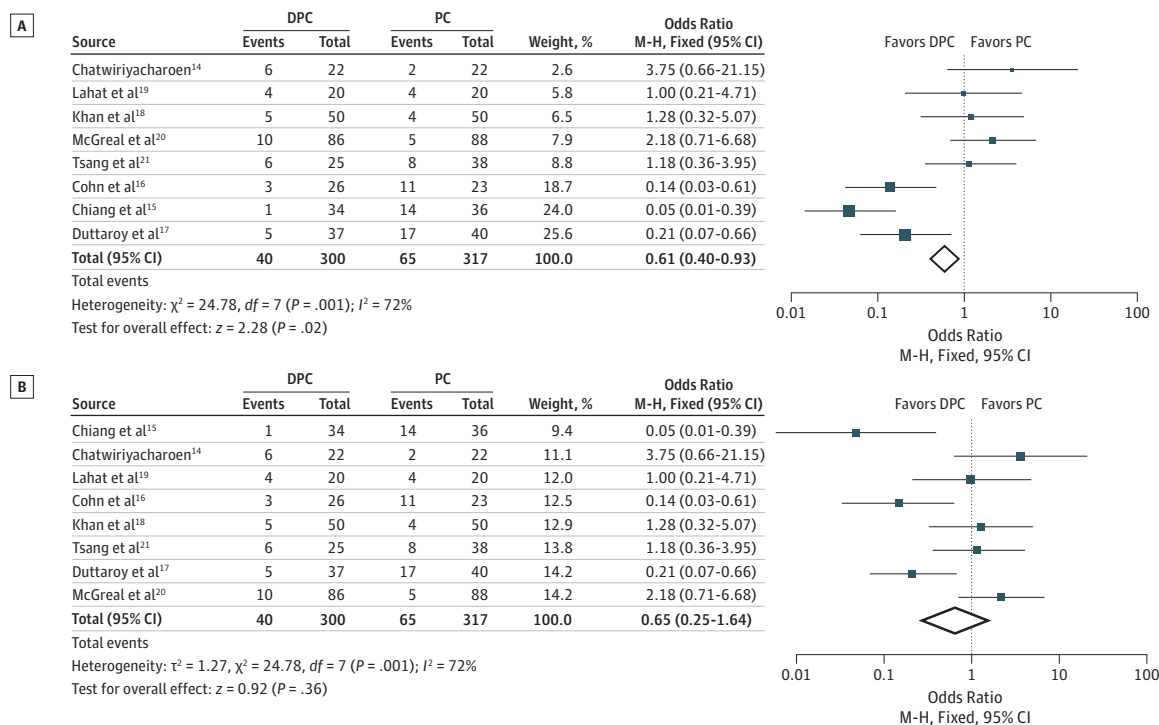
Abbreviations: CDC, Centers for Disease Control and Prevention; DPC, delayed primary closure; I&D, incision and drainage; PC, primary closure.

model was not significant. For appendicitis only studies, the reverse was found; there was a reduction in length of stay with a fixed-effects model but it was nonsignificant with a random-effects model. Healing by secondary intention and readmission were not significantly different between DPC and PC for all studies or appendicitis only studies, by either fixed-effects or random-effects models.

## Discussion

Finding a reliable method to reduce SSI following abdominal surgery is an international research priority. Surgical site infection carries significant morbidity and financial cost and, when assessed prospectively and accurately, affects more pa-

Figure 2. Forest Plots Illustrating Meta-analysis of Surgical Site Infections by Delayed Primary Closure (DPC) vs Primary Closure (PC)



The effects are shown using fixed-effects (A) and random-effects (B) models. M-H indicates Mantel-Haenszel.

Table 3. Meta-analysis of Outcomes for All Studies and Patients Undergoing Appendectomy Only

Outcome	No. of Studies	Total No. of Patients	Heterogeneity		P Value	Effect	OR or WMD (95% CI)	P Value
			$I^2$ , %	$\chi^2$				
All studies								
SSI	8	617	72	24.8	<.001	FE	0.61 (0.40 to 0.93)	.02
						RE	0.65 (0.25 to 1.64)	.36
Length of stay	5	428	98	261	<.001	FE	0.34 (0.16 to 0.53)	<.001
						RE	0.20 (-1.42 to 1.83)	.81
Secondary intention healing	4	337	41	5.1	.17	FE	0.96 (0.45 to 2.03)	.92
						RE	1.13 (0.33 to 3.95)	.84
Readmission	2	244	50	2.01	.16	FE	1.04 (0.23 to 4.66)	.96
						RE	0.97 (0.07 to 14.16)	.98
Appendectomy only <sup>a</sup>								
SSI	6	468	70	16.7	.005	FE	0.82 (0.49 to 1.37)	.45
						RE	0.78 (0.24 to 2.58)	.69
Length of stay	3	288	98	92.6	<.001	FE	-0.85 (-1.11 to -0.59)	<.001
						RE	-0.41 (-2.23 to 1.42)	.66
Readmission	2	244	50	2.01	.16	FE	1.04 (0.23 to 4.66)	.96
						RE	0.97 (0.07 to 14.16)	.98

Abbreviations: FE, fixed effect; OR, odds ratio; RE, random effect; SSI, surgical site infection; WMD, weighted mean difference.

<sup>a</sup> Poolable data from more than 1 study for secondary intention healing were not available.

tients than previously thought. Many single measures in individual RCTs have been proven to reduce SSI. These measures include surgical hand preparation,<sup>23</sup> appropriate

antibiotic prophylaxis,<sup>24</sup> and postponing of an elective operation in the case of active remote infection.<sup>25</sup> Although there appears to be no difference in SSI in patients who have had hair



removed from the surgical site compared with no hair removal,<sup>26</sup> clipping before surgery rather than shaving is recommended in current UK national guidelines.<sup>27</sup> As early as 1985, the Study on the Efficacy of Nosocomial Infection Control showed that the involvement of a dedicated infection control team with surveillance and feedback of observed wound infection data resulted in a 38% decrease of SSI among participating hospitals.

Other measures that have been recommended to reduce SSI include supplemental oxygen use,<sup>5,6</sup> no bowel preparation in elective bowel resection,<sup>28</sup> preoperative skin antiseptics,<sup>29</sup> perioperative normothermia,<sup>8</sup> intravenous fluid restriction,<sup>30</sup> antimicrobial-impregnated sutures,<sup>31</sup> wound edge protection devices,<sup>7</sup> and tight glycemic control. While a meta-analysis<sup>32</sup> from 2009 found insufficient evidence to support strict glycemic control vs conventional management (maintenance of glucose level <200 mg/dL [to convert to millimoles per liter, multiply by 0.0555]) for the prevention of SSI, a recent publication from the Surgical Care and Outcomes Assessment Program in Washington State reported that patients with postoperative hyperglycemia had a significantly increased risk of infection, operative reinterventions, and death. This increased morbidity was independent of whether the patient was known preoperatively to have diabetes.<sup>33</sup>

However, some of these measures have recently been challenged, with Bayesian meta-analysis suggesting overestimation of treatment effects for perioperative supplemental oxygen<sup>34</sup> and long-term follow-up showing a higher mortality in cancer patients when high oxygen fractionation was used.<sup>35</sup> A meta-analysis of 7 RCTs evaluating the placement of antimicrobial sutures failed to confirm any benefit in reducing SSI.<sup>22</sup> Laminar air flow in the operating room has been shown to reduce bacterial count in the air<sup>36</sup> but not to reduce the rate of SSI.<sup>37</sup>

If a single factor has been found to reduce SSI, then combining different factors into “bundles of care” and expecting them to work synergistically is an attractive idea. Trussell et al<sup>38</sup> implemented a perioperative care bundle including hair clipping, antibiotic prophylaxis, and close glucose control and reported an SSI rate of 1.5% in the intervention group compared with 3.5% in the comparator arm. However, Anthony et al<sup>1</sup> performed a well-designed RCT to assess an evidence-based bundle of care, randomizing between standard practice or a bundle of interventions consisting of (1) omission of mechanical bowel preparation; (2) preoperative and intraoperative warming; (3) supplemental oxygen during and immediately after surgery; (4) intraoperative intravenous fluid restriction; and (5) use of a surgical wound protector. They prospectively and proactively assessed SSI according to the criteria provided by the Centers for Disease Control and Prevention. Unexpectedly, they found a high rate of SSI (45%) in the group undergoing the “extended” bundle of interventions compared with 24% in the standard arm ( $P = .003$ ). The reason for this surprising result, especially when each individual strategy had supporting RCT evidence, was not immediately apparent. It may have been that the evidence supporting the individual measures is not correct or that the combined effects carried unpredictable outcomes.

Vacuum-assisted techniques to assist early wound closure have gained popularity in both civilian and military patients through their ability to facilitate early fascial closure in the presence of complex and contaminated wounds.<sup>39,40</sup> Although initial focus was placed on management of the open abdomen, vacuum therapy with initial fascial closure, as an adjunct to DPC, is an attractive option. It potentially allows control of effluent from the wound, decreases the burden on nursing care, and is especially attractive during long-range evacuation of combat casualties.<sup>41</sup> However, further evidence for its efficacy and safety is required following abdominal surgery, ideally from randomized trials, although these will prove difficult because of methodological constraints.

Delayed primary skin closure is accepted as the optimal method to treat wounds of war.<sup>42</sup> Complex soft tissue injuries sustained during combat are still debrided and closed in a staged fashion (although the dressings used in the interim may have changed).<sup>41</sup> The simplicity and effectiveness of this wound care policy has led some to extrapolate the technique to contaminated surgical wounds. Velmahos et al<sup>43</sup> performed an RCT comparing primary vs planned secondary wound healing following operations for 48 patients with colon injuries. They found that planned healing by secondary intention almost halved the rate of wound infections (65% vs 36%;  $P = .04$ ).

The RCTs included in this meta-analysis were all deemed to be at high risk of bias because of flaws in design, methods, and outcome assessment. Furthermore, they were all small-numbered trials. Both fixed-effects and random-effects meta-analyses were applied to take account of this and interpret the likely resultant heterogeneity. While a fixed-effects meta-analysis is based on the mathematical assumptions that a single common effect underlies every study, a random-effects meta-analysis makes the assumption that individual studies are estimating different treatment effects.<sup>44</sup> A great deal of debate exists over which is better to use for meta-analysis; this study presented both. Considering all studies, the fixed-effects OR for SSI showed a significant reduction with DPC, but the random-effects model was not significant between DPC and PC, suggesting significant heterogeneity and bias between studies.

Differences between random- and fixed-effects models may have been caused by the differences in inclusion criteria, underlying diagnoses, and outcome assessment between studies. While surgical technique may have varied, the single-center and sometimes single-surgeon nature of these studies may limit intraoperative variability. It is still reasonable that these studies are clinically comparable because of the contaminated nature of the included abdominal wounds. The significant reduction showed by the fixed-effects model suggests that a well-designed trial may prove a definitive reduction in SSI.

A possible advantage of DPC is its potential cost-effectiveness. It requires no extra specialist equipment and may thus have a global appeal if proven effective. This technique may also have a role in austere or deployed military and developing world settings, where contamination is common and microbiological profiles are varied and diverse. However, the widespread applicability in civilian environments is yet to be deter-

mined because of the sharp contrast with austere war settings. Military surgeons may continue to leave wounds open because of the high rate of tissue destruction, shock, contamination, and cavitation, in keeping with damage control principles.

The included studies contained no data on cost-effectiveness, quality of life, pain outcomes, or the morbidity of the burden of an open wound. Mitigating any possible cost improvement is a potential effect of DPC on prolonged length of stay. The differences in length of stay seen in this study (both significant and nonsignificant) carried low clinical relevance (between -0.85 and 0.34 days). By reducing the rate of SSI, DPC may offset the time required to pack, reassess, and then definitively close the skin.

Although no overall benefit was seen, the methodological limitations of the included trials may have eliminated an underlying consistent benefit, as seen in at least 1 study.<sup>16</sup> Only 2 studies in the present meta-analysis cited Centers for Disease Control and Prevention criteria, and when combined with uncertainty over who performed wound inspection, it is highly likely that not all SSIs were identified. Thus, DPC warrants further attention. To control and stratify for the heterogeneous

group of operations that lead to contaminated and dirty abdominal wounds, a randomized trial is required. To produce a meaningful and generalizable result, a multicenter setting would be required, from an international group and, ideally, with a contribution from the developing world. Adequate definitions of methods of performing DPC, blinding, and active wound assessment methods with standardized SSI definitions would also be required. However, such a trial would prove challenging, in part because of the difficulty in obtaining true clinical equipoise from surgeons.

## Conclusions

Delayed primary skin closure may represent a simple, reliable, and potentially cost-effective way of reducing SSI following abdominal surgery with contaminated or dirty wounds, but the current literature fails to provide definitive evidence. The methodological design of published studies is poor, with a clinical and statistical heterogeneity and a high risk of bias. A well-designed, large-numbered multicenter RCT is warranted.

### ARTICLE INFORMATION

**Accepted for Publication:** February 26, 2013.

**Published Online:** June 26, 2013.  
doi:10.1001/jamasurg.2013.2336.

**Author Contributions:** *Study concept and design:* Bhangu, Singh, Lundy, and Bowley.  
*Acquisition of data:* Bhangu and Singh.  
*Analysis and interpretation of data:* Bhangu.  
*Drafting of the manuscript:* Bhangu, Singh, and Bowley.

*Critical revision of the manuscript for important intellectual content:* Bhangu, Singh, Lundy, and Bowley.

*Statistical analysis:* Bhangu and Singh.

*Administrative, technical, and material support:* Lundy.

*Study supervision:* Bowley.

**Conflict of Interest Disclosures:** None reported.

**Role of the Sponsor:** The opinions stated are those of the authors and not the UK Ministry of Defence or the US Department of Defense.

**Correction:** This article was corrected on September 10, 2013, to fix incorrect information in the Primary Outcome subsection of the Results section and in Table 1, Table 2, and Figure 2.

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## Invited Commentary

# Please Pack Open Your Dirty Wounds!

Stephen M. Cohn, MD

*Suppuration may be considered a resolution but it is a mode of resolution which we mainly wish to avoid.*

John Hunter (1728-1793)

**Bhangu and colleagues<sup>1</sup> recently** performed a review of the literature comparing the impact of wound management with delayed primary closure (DPC) vs primary closure (PC) on subsequent wound infection. They analyzed 8 randomized trials



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that they found to be highly heterogeneous and some quite flawed. Most studies did not establish uniform techniques for wound care and some failed to strictly define wound infection or how the presence of this complication was adjudicated. Not surprisingly, the outcomes were inconsistent, their meta-analysis showed a large amount of variability and bias, and the final results were inconclusive. It appears that sloppy methods eliminated the potential to identify consistent benefit to a particular technique in the majority of prior investigations.

Unfortunately, there is difficulty in obtaining clinical equipoise to perform large randomized trials because most experienced surgeons have strong opinions about the proper handling of dirty wounds. The acute care/trauma surgeons (the “slime team”) have a steady diet of dirty cases and have a view biased by the high number of infections encountered when wounds are closed in complex patients. Private practitioners rarely encounter dirty wounds among their high volume of elective cases and therefore typically close all the wounds in their practice. We reached clinical equipoise some years ago and conducted a study in adults with dirty wounds, randomized to DPC or PC, with a strict technique of DPC defined, and blinded clinical assessors. The use of DPC had a clinically relevant and statistically significant benefit (12% wound infection after DPC vs 48% in PC;  $P = .01$ ).<sup>2</sup>

While the limitations of many studies preclude solid conclusions, there remain some convincing data that using a consistent method of DPC will reduce the incidence of wound infection in the setting of dirty wounds.



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**Published Online:** June 26, 2013.  
doi:10.1001/jamasurg.2013.2343.

**Conflict of Interest Disclosures:** None reported. (71.7 [13.8])

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