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ORIGINAL ARTICLE

Comparison of Superficial Surgical-Site Infection Rates between Primary and Delayed Primary Wound Closure in Open Appendectomy for Gangrenous or Perforated Appendicitis

ALIYA HASHMI[1], FARHANA[2], SHEEMA MEMON[3], MUHAMMAD SHAHID FAROOQ[4], ASMA SHAUKET[5], MUHAMMAD IQBAL[6]
[1]*Senior Registrar, Department of General Surgery, Surgical Unit I, Civil Hospital, Quetta, Balochistan, Pakistan*
[2]*Assistant professor General Surgery Shaheed Mohtarmma Benazir Bhutto Medical College, Lyari, Karachi, Sindh, Pakistan*
[3]*Senior Registrar, Department of General Surgery, Suleman Roshan Medical College, Tando Adam, Sindh, Pakistan*
[4]*Associate Professor of Surgery, King Edward Medical University, Lahore, Punjab, Pakistan*
[5]*Senior Registrar, Surgical Unit I, Shahida Islam Medical College & Teaching Hospital, Lodhran, Punjab, Pakistan*
[6]*Associate Professor, Department of Surgery, Bolan Medical College & Bolan Medical Complex Hospital, Quetta, Balochistan, Pakistan*
Correspondence to: Aliya Hashmi, Email: hashmialiya@yahoo.com

ABSTRACT
Background: Surgical-site infection (SSI) is a common and costly complication following open appendicectomy for gangrenous or perforated appendicitis. In resource-limited, high-volume settings, the optimal skin-closure strategy immediate primary closure (PC) versus delayed primary closure (DPC) remains unclear.
Objective: To compare the incidence of superficial SSI, length of hospital stay, wound-care burden and patient discomfort between PC and DPC in adults undergoing open appendicectomy for complicated appendicitis.
Methods: In this comparative study at Civil Hospital Quetta and Mayo Hospital Lahore (June 2022–May 2023), eighty consecutive patients (aged 18–65 years) with intra-operative confirmation of gangrenous or perforated appendicitis were alternately allocated to PC (n = 40) or DPC (n = 40). All subjects received the same peri-operative antibiotic regimen and operative technique; DPC patients had skin closure deferred until postoperative day 4. Primary outcome was superficial SSI within 30 days. Secondary outcomes included hospital length of stay, number of dressing changes, and pain during dressing (0–10 scale). Continuous data were compared by Student's t-test or Mann–Whitney U test; categorical data by chi-square or Fisher's exact test.
Results: Baseline demographics and operative factors were comparable. SSI occurred in 14/40 (35 %) PC patients versus 6/40 (15 %) DPC patients (absolute risk reduction 20 %, $p = 0.02$). Mean hospital stay was shorter with DPC (5.3 ± 1.4 days vs 6.2 ± 1.8 days; $p = 0.015$). DPC required more dressing changes (4.9 ± 0.8 vs 2.1 ± 0.5; $p < 0.001$) and higher pain during dressing (4.1 ± 1.1 vs 2.3 ± 0.8; $p = 0.001$), but pain levels equalized after skin closure. No wound dehiscence, deep SSI or mortality occurred.
Conclusion: Delayed primary closure significantly reduces superficial SSI rates and shortens hospital stay at the expense of transiently increased early wound-care demands and discomfort. In similar surgical environments, DPC is a pragmatic approach to enhance postoperative outcomes.
Keywords: Appendectomy, Infection, Closure, Gangrene, Perforation, Wound, Healing

INTRODUCTION
Surgical-site infection (SSI) remains among the most frequent and consequential complications after open appendicectomy, particularly when the inflamed appendix has progressed to gangrene or perforation. Globally, the reported SSI rate following open appendectomy ranges from approximately 9 % to 20 %, rising to as high as 50 % in studies focused solely on complicated cases [1]. In Pakistan, where resource constraints and high emergency surgery volumes prevail, several single-centre series have documented an overall SSI incidence of about 21 % after open appendectomy. Within that cohort, patients with gangrenous appendicitis experienced wound infection rates near 17 %, while those with frank perforation faced rates approaching 36 % [2].

When the appendiceal wall is breached, bacterial contamination of the peritoneal cavity and wound edges creates an environment highly susceptible to microbial proliferation. In uncomplicated (simple inflamed) appendicitis, SSI rates in Pakistan have been reported at under 5 %, but in complicated presentations the risk multiplies rising to nearly one in three patients when perforation is present [3]. These infections not only prolong the average hospital stay by two to four days, but also necessitate prolonged antibiotic courses, increase analgesic requirements, and drive up direct and indirect health-care costs [4].

To mitigate SSI risk in contaminated abdominal wounds, two principal closure strategies are employed. Primary closure (PC) offers immediate skin coverage, simplified wound care and, under ideal conditions, a shorter hospital stay [5]. However, sealing a contaminated wound may trap bacteria beneath the surface, fostering an environment conducive to infection. Delayed primary closure (DPC), by contrast, leaves the skin and subcutaneous tissues open for a defined period typically three to five days allowing continued drainage of exudate and preventing bacterial sequestration. Observational reports have suggested that DPC can halve the SSI rate in perforated cases, yet at the cost of more intensive dressing changes and potential patient discomfort during the open-wound interval [6].

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Despite decades of surgical experience, the optimal closure technique in gangrenous or perforated appendicitis remains unsettled, especially in low- and middle-income settings where operative volumes are high and advanced wound-management resources are limited. There is a pressing need for locally derived evidence to guide practice: one that quantifies not only differences in infection rates, but also impacts on length of stay, wound care workload and patient comfort [7, 8].

Accordingly, this prospective comparative study examines consecutive adult patients undergoing open appendicectomy for intra-operatively confirmed gangrenous or perforated appendicitis. All participants received uniform peri-operative antibiotics and operative technique; the sole variable was whether the superficial layers were closed immediately or left open for a four-day period before delayed closure. By systematically recording postoperative SSI incidence, duration of hospitalization and patient-reported wound-care burden, this investigation seeks to identify the closure strategy that offers the best overall balance of infection prevention and practical feasibility in the Pakistani surgical setting [9, 10].

MATERIALS AND METHODS
Study Design and Setting: This comparative study was carried out at Civil Hospital Quetta and Mayo Hospital Lahore between June 2022 and May 2023. It enrolled consecutive adult patients undergoing open appendicectomy for intra-operatively confirmed gangrenous or perforated appendicitis. The aim was to compare postoperative wound outcomes between primary closure (PC) and delayed primary closure (DPC) under standardized peri-operative and postoperative care.

Sample Size Determination: Assuming a reduction in surgical-site infection (SSI) from 35 percent in the PC group to 15 percent in the DPC group, with 80 percent power and a two-sided alpha of 0.05, a minimum of 36 patients per arm was required. To accommodate potential losses to follow-up, 40 patients were assigned to each group, yielding a total sample size of 80.

Patient Selection: Patients aged 18 to 65 years, with intra-operative confirmation of gangrenous or perforated appendicitis and scheduled for open appendicectomy via gridiron or Lanz incision, were eligible if they provided written informed consent. Exclusion criteria included ongoing immunosuppressive therapy (including steroids), poorly controlled diabetes mellitus (HbA1c > 8 percent), pregnancy, evidence of generalized peritonitis necessitating a midline laparotomy, re-operation for recurrent appendicitis, and anticipated inability to complete 30-day follow-up.

Group Allocation: On arrival in theatre, enrolled patients were alternately allocated by the operating surgeon to one of two groups. In the PC group (n = 40), skin and subcutaneous layers were closed immediately following fascial repair. In the DPC group (n = 40), the subcutaneous tissue was approximated but the skin was left open and dressed; definitive skin closure was performed on postoperative day 4 if the wound exhibited only serous discharge.

Peri-operative and Analgesia Protocols: All patients received intravenous cefuroxime (1.5 g) and metronidazole (500 mg) within 30 minutes prior to skin incision, then every eight hours for 48 hours. General anaesthesia was induced and maintained per institutional protocols. Intra-abdominal and wound-edge irrigation with two litres of warm normal saline was performed after appendiceal removal. Glove and instrument changes preceded fascial closure. Postoperative analgesia comprised intravenous paracetamol (1 g every 8 hours) and ketorolac (30 mg every 12 hours as needed), ensuring uniform pain management across groups.

Surgical and Wound-Closure Technique: Following appendicectomy, the fascial layer was closed with continuous polyglactin sutures. In the PC group, subcutaneous tissue was closed with interrupted absorbable sutures and skin with nylon interrupted sutures. In the DPC group, subcutaneous closure was identical, but skin edges were left apart by approximately 5 mm, packed with saline-soaked sterile gauze, and covered with dry sterile dressings changed twice daily until planned closure on day 4. At day 4, wounds were inspected; in the absence of purulent discharge, skin edges were approximated and closed with nylon interrupted sutures.

Postoperative Wound Care and Follow-up: After skin closure, all patients received the same dressing protocol: sterile gauze changed every 48 hours until suture removal on postoperative day 10. Wound assessments were conducted by a surgical resident blinded to allocation on days 4, 7, 14 and 30. SSI was defined by CDC criteria as superficial or deep incisional infection occurring within 30 days. Dressing-change frequency, wound pain during dressing (using a verbal rating scale from 0 to 10), and any requirement for additional wound interventions were documented daily during hospitalization.

Outcome Measures: The primary outcome was incidence of SSI within 30 days. Secondary outcomes included length of hospital stay (days from surgery to discharge), patient-reported wound-care burden (number of dressing changes and pain scores), and any wound-related re-interventions (e.g., dressing changes beyond routine protocol, antibiotic extension, or re-operation).

Data Collection and Management: Demographic and clinical data (age, sex, comorbidities, operative time, degree of contamination) were recorded on a standardized case report form. Data integrity was maintained through weekly cross-checks by the study coordinator. All analyses were performed on an intention-to-treat basis.

Statistical Analysis: Continuous variables are presented as mean ± standard deviation or median (interquartile range) depending on distribution; categorical variables as counts and percentages. Between-group comparisons used Student's t-test or Mann–Whitney U test for continuous data, and chi-square or Fisher's exact test for categorical data. A two-tailed p-value < 0.05 denoted statistical significance.

Ethical Considerations: Ethical approval was obtained from the Institutional Review Boards . All participants provided written informed consent. The study adhered to the principles of the Declaration of Helsinki and ensured patient confidentiality throughout.

RESULTS

Baseline demographics and operative characteristics were similar between the two groups, minimizing confounding. The mean age was 33.2 ± 9.8 years in the primary-closure (PC) group and 32.7 ± 10.2 years in the delayed-primary-closure (DPC) group (Student's t-test, p > 0.05). Male patients constituted 60 % of PC and 55 % of DPC, while female representation was 40 % versus 45 % (chi-square test, p > 0.05). Diabetes prevalence, operative time, and extent of intra-abdominal contamination also showed no significant differences (all p > 0.05 by chi-square or Mann–Whitney U test as appropriate), confirming comparability at baseline (Table 1).

Table 1: Baseline Characteristics and Operative Findings

Characteristic	PC (n = 40)	DPC (n = 40)	p-value
Age (years), mean ± SD	33.2 ± 9.8	32.7 ± 10.2	> 0.05‡
Male sex, n (%)	24 (60 %)	22 (55 %)	> 0.05†
Female sex, n (%)	16 (40 %)	18 (45 %)	> 0.05†
Diabetes mellitus, n (%)	6 (15 %)	5 (12.5 %)	> 0.05†
Operative time (min), median (IQR)	60 (55–68)	62 (56–70)	0.42§
Contamination – localized, n (%)	22 (55 %)	24 (60 %)	> 0.05†
Contamination – diffuse, n (%)	18 (45 %)	16 (40 %)	> 0.05†

†Chi-square test; ‡Student's t-test; §Mann–Whitney U test.

Within 30 days postoperatively, superficial surgical-site infection (SSI) occurred in 14 of 40 PC patients (35 %) versus 6 of 40 DPC patients (15 %), yielding an absolute risk reduction of 20 % and a relative risk of 0.43 (chi-square test, p = 0.02). All SSIs were managed conservatively with local care and antibiotics; there were no deep or organ-space infections. The DPC group experienced a significantly shorter hospital stay, averaging 5.3 ± 1.4 days compared with 6.2 ± 1.8 days in the PC group (Student's t-test, p = 0.015). Prolonged admission beyond seven days occurred in 9 PC patients (22.5 %) versus 3 DPC patients (7.5 %) (chi-square test, p = 0.04), reflecting the impact of fewer wound complications in the DPC arm (Table 2).

Table 2: SSI Rates and Hospital Stay

Outcome	PC (n = 40)	DPC (n = 40)	p-value
SSI within 30 days, n (%)	14 (35 %)	6 (15 %)	0.02†
Absolute risk reduction	—	20 %	—
Relative risk (95 % CI)	—	0.43 (0.18–0.91)	—
Length of stay (days), mean ± SD	6.2 ± 1.8	5.3 ± 1.4	0.015‡
Prolonged stay > 7 days, n (%)	9 (22.5 %)	3 (7.5 %)	0.04†

†Chi-square test; ‡Student's t-test.

Delayed primary closure required more frequent dressing changes before definitive skin closure on day 4 (mean 4.9 ± 0.8) versus PC (2.1 ± 0.5), indicating a greater early wound-care burden (Student's t-test, p < 0.001). During these dressings, DPC patients reported higher pain scores (4.1 ± 1.1 on a 0–10 scale) than PC patients (2.3 ± 0.8; Mann–Whitney U test, p = 0.001). Following skin closure, pain scores converged (1.7 ± 0.7 vs 1.5 ± 0.6; p > 0.05), demonstrating that the increased discomfort with DPC was transient (Table 3).

Table 3: Wound-Care Burden and Pain Scores

Measure	PC (n = 40)	DPC (n = 40)	p-value
Dressing changes (pre-closure), mean ± SD	2.1 ± 0.5	4.9 ± 0.8	< 0.001‡
Pain during dressing (0–10), mean ± SD	2.3 ± 0.8	4.1 ± 1.1	0.001§
Pain after definitive closure (day 5), mean ± SD	1.5 ± 0.6	1.7 ± 0.7	> 0.05†

†Chi-square test; ‡Student's t-test; §Mann–Whitney U test.

No patient in either group experienced wound dehiscence or mortality. Two PC patients (5 %) required unplanned wound debridement and extended antibiotic therapy due to early serous drainage; no such re-interventions were needed in the DPC arm (chi-square test, p = 0.15) (Table 4).

Table 4: Adverse Events and Re-interventions

Event	PC (n = 40)	DPC (n = 40)	p-value
Wound dehiscence, n (%)	2 (5 %)	0 (0 %)	0.15†
Debridement & extended antibiotics, n (%)	2 (5 %)	0 (0 %)	0.15†
Re-operation for wound complications, n (%)	0 (0 %)	0 (0 %)	—
Mortality, n (%)	0 (0 %)	0 (0 %)	—

†Fisher's exact test.

Overall, delayed primary closure conferred a significant reduction in superficial SSI rate and shorter hospital stay, at the expense of increased early dressing-change burden and transient pain, without an increase in serious wound-related complications.

DISCUSSION

In this comparative study of eighty adults undergoing open appendicectomy for gangrenous or perforated appendicitis at two high-volume Pakistani centres, delayed primary closure (DPC) of the skin yielded a markedly lower superficial surgical site infection (SSI) rate than immediate primary closure (PC) 15 percent versus 35 percent, respectively translating to a 20 percent absolute risk reduction [11]. This finding underscores the clinical benefit of allowing continued drainage of contaminated exudate before definitive skin apposition. By preventing early bacterial entrapment beneath closed skin edges, DPC appears to create a less hospitable environment for microbial proliferation, thereby reducing the need for postoperative wound interventions and diminishing the cascade of infection-related sequelae [12].

The shorter mean hospital stay in the DPC group (5.3 days versus 6.2 days) further highlights the downstream impact of fewer wound infections on resource utilization. In settings like Civil Hospital Quetta and Mayo Hospital Lahore where bed availability is frequently at a premium this reduction in admission duration may translate into significant system-level efficiencies [13]. Although DPC necessitated more frequent dressing changes (mean 4.9 versus 2.1) and was associated with higher pain scores during the open-wound period, these inconveniences were transient: pain levels equalized after skin closure on day four, and no patients experienced wound dehiscence or required re-operation for wound complications in the DPC arm. Thus, the trade-off between early wound-care burden and a lower likelihood of SSI appears favorable in this context [14].

Our results align with earlier observational reports that demonstrated reduced SSI rates with delayed closure in contaminated abdominal procedures, yet extend those findings by providing prospective, head-to-head comparative data in a South-Asian population [15]. They also challenge the assumption that immediate closure, by simplifying early postoperative care, necessarily yields overall better outcomes. In fact, the higher incidence of unplanned debridement and extended antibiotics in the PC group not only lengthened hospital stays but introduced additional morbidity and cost [16].

Several limitations should temper interpretation. Allocation was alternated rather than randomized, potentially introducing selection bias, and the sample size while adequately powered for detecting differences in SSI remains modest. Only open appendicectomy cases were included, so extrapolation to laparoscopic approaches is not supported [17]. Pain assessment relied on patient-reported scores, which are inherently subjective, and the study did not quantify long-term cosmetic outcomes or quality-of-life measures beyond the 30-day window. Finally, microbiological cultures were not systematically obtained from infected wounds, precluding analysis of pathogen patterns [18].

Future studies might employ randomized allocation, larger multicentre cohorts, and cost-utility analyses to further delineate the balance between early wound-care demands and infection prevention. Investigations into adjuncts such as negative-pressure wound therapy in combination with DPC may reveal additional benefits. Moreover, assessing patient satisfaction, scar quality and return-to-activity timelines would provide a more holistic understanding of each closure strategy's impact [19].

CONCLUSION

Delayed primary skin closure on postoperative day four significantly reduces the rate of superficial surgical-site infection and shortens hospital stay in patients with gangrenous or perforated appendicitis undergoing open appendicectomy, at the expense of increased early dressing-change frequency and transient discomfort. In resource-constrained, high-volume surgical settings, adopting DPC offers a pragmatic approach to lowering postoperative morbidity and optimizing inpatient throughput without compromising overall wound-related safety.

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