

# Risk Factors for Wound Infections after Vascular Surgery: Kuwait Experience

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## Highlights of the Study

- This review examines risk factors for post-operative wound infections in patients undergoing open vascular surgical procedures in Kuwait.
- Risk factors significantly associated with the development of wound infections included diabetes mellitus, hypertension, ischemic heart disease, hyperlipidemia, and chronic kidney disease.
- Atherosclerotic risk factors not significantly associated with the development of wound infections included age older than 65 years, male gender, smoking, and stroke.

## Keywords

Vascular surgery · Peripheral arterial disease · Arterial aneurysms · Wound infection · Post-operative complications

## Abstract

**Introduction:** Wound infections represent a serious complication after vascular surgery particularly after vascular reconstructive procedures. We aimed to identify risk factors predisposing patients to these complications. **Methods:** This was a retrospective review of open vascular surgical procedures performed between April 2014 and March 2019 in Kuwait. Patient demographics, procedures performed and their indications, and post-operative outcomes were collected and analyzed. Patients with pre-operative active infections were excluded from the analysis. Statistical analysis was performed, and odds ratios (ORs) and relative risks were calculated for the outcomes of interest. Fisher's exact test

and two-tailed *t* test were used where appropriate. **Results:** 391 patients were identified. The majority (54%) presented with chronic limb threatening ischemia. The mean age was 58 ( $\pm 10$ ) years, with a male predominance (76%). Wound infection occurred in 53 (14%) patients. The most commonly isolated organism was *Staphylococcus aureus* (47%). Diabetes (OR 8.03, 95% CI: 1.9142–33.7439,  $p = 0.0044$ ), hypertension (OR 2.38, 95% CI: 1.2960–4.3684,  $p = 0.0052$ ), ischemic heart disease (OR 2.30, 95% CI: 1.4349–4.6987,  $p = 0.0016$ ), hyperlipidemia (OR 2.12, 95% CI: 1.0305–4.3620,  $p = 0.0412$ ), and chronic renal failure (OR 2.55, 95% CI: 1.0181–6.4115,  $p = 0.0457$ ) were all found to be significantly associated with the development of post-operative wound infections in vascular surgery patients. **Conclusion:** Diabetes, hypertension, ischemic heart disease, hyperlipidemia, and chronic renal failure were associated with post-operative wound infections. Anticipation of wound complications in patients with these risk factors may aid early diagnosis and treatment.

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## Introduction

Wound infections represent a serious complication after vascular surgery especially after vascular reconstructive procedures. The economic burden of this is substantial, depending on the depth of the infection and patient comorbidities [1]. Deep-seated infections are more troublesome than their superficial counterparts, and extension to the vascular suture line may lead to fatal hemorrhagic complications. The groin region is the most common location for surgical site infection accounting for 55–77% of cases [2, 3]. The reported surgical wound infection rate in clean procedures is between 1% and 5.4%; however, vascular wound infections occur at a higher rate (between 1.5% and 14.8%), possibly due to the presence of several risk factors in this patient population [4]. We aimed to identify those risk factors that predispose our patient population to these complications.

## Methods

We performed a retrospective review of all open vascular surgical procedures conducted between April 2014 and March 2019. The study was carried out in the main vascular surgery unit in Kuwait at Mubarak Al-Kabeer Hospital. All procedures were extracted from the operating room patient log, and patient files were requested from medical records. Data collected included patient demographics and risk factors, indications for surgery, procedures performed, and post-operative outcomes including wound infections. Existing patient information collected was de-identified after collecting all the desired data; patients were then given a unique study ID, and the original data with identifiers were discarded. This study qualified for exempt status and individual patient consent was not required.

All patients were cleaned with chlorhexidine bath prior to the operation. The operative site was shaved in the operating room on the day of the procedure. Patients were scrubbed with povidone iodine prior to making an incision. Pre-operative antibiotics (3rd-generation cephalosporin) were administered within 1 h of making incision. Groin incisions were closed in multiple layers. Immediate post-operative care included administration of supplemental oxygen and monitoring of oxygen saturation and glucose levels. Infections were diagnosed based on clinical signs and symptoms; we included cases where there was a clear diagnosis in the chart and/or the patient was started on therapeutic antibiotics with or without procedural debridement for their surgical wound. Additional imaging was obtained when deep infection was suspected. All wounds were cultured, and targeted intravenous antibiotic therapy was used to treat all patients. Patients with pre-operative active infections were excluded from the analysis, while those with peri-operative infections were included. The study population was then split into two groups, those with and those without wound infections. Risk factors were statistically analyzed, comparing the two groups. A literature review was performed to identify studies with post-operative vascular surgical infections, and a comparison was made to our patient cohort.

**Table 1.** Patient demographics and procedural indications

|                                |          |
|--------------------------------|----------|
| Demographics ( <i>n</i> = 391) |          |
| Male                           | 296 (76) |
| Age, years (mean ± SD)         | 58±10    |
| DM                             | 308 (79) |
| HTN                            | 187 (48) |
| Smoking                        | 197 (50) |
| CVA                            | 56 (14)  |
| Ischemic heart disease         | 157 (40) |
| HLD                            | 53 (14)  |
| CKD                            | 26 (7)   |
| Indications ( <i>n</i> = 391)  |          |
| Aneurysm                       | 28 (8)   |
| Claudication                   | 150 (38) |
| Rest pain                      | 134 (34) |
| Ulcer/gangrene                 | 79 (20)  |

Values are *n* (%) unless otherwise indicated. DM, diabetes mellitus; CVA, cerebrovascular accident; CKD, chronic kidney disease.

**Table 2.** Vascular procedures performed and types of conduit used

|                                       | <i>n</i> (%) |
|---------------------------------------|--------------|
| Total surgery ( <i>n</i> = 391)       |              |
| Procedures ( <i>n</i> = 84)           |              |
| Primary amputation                    | 26 (7)       |
| Exploration alone                     | 9 (2)        |
| Thrombectomy and embolectomy          | 35 (9)       |
| Patch angioplasty                     | 12 (3)       |
| Patch angioplasty with endarterectomy | 2 (1)        |
| Bypasses ( <i>n</i> = 307)            |              |
| Aorto-bifemoral                       | 43 (11)      |
| Ilio-femoral                          | 37 (9)       |
| Femoro-femoral                        | 17 (4)       |
| Axillo-bifemoral                      | 6 (2)        |
| Femoro-popliteal (above knee)         | 86 (22)      |
| Femoro-popliteal (below knee)         | 78 (20)      |
| Femoro-distal                         | 40 (10)      |
| Type of graft ( <i>n</i> = 307)       |              |
| Vein                                  | 108 (35)     |
| Synthetic                             | 189 (62)     |
| Composite                             | 10 (3)       |

Statistical analysis was performed using SPSS (SPSS Inc., Chicago, IL, USA), and univariate odds ratios (ORs) and relative risks were calculated for the outcomes of interest. Multivariate logistic regression was also performed for the variables. Fisher's exact test and two-tailed *t* test were used where appropriate. A *p* value of 0.05 or less was considered significant. All means are reported with standard deviation, medians with lowest and highest values, and effect size with 95% confidence interval (CI).

**Table 3.** RR of wound infection with different risk factors

|         | Infection, n = 53 | No infection, n = 338 | RR     | 95% CI         | p value |
|---------|-------------------|-----------------------|--------|----------------|---------|
| Age >65 | 18                | 93                    | 1.2973 | 0.7680–2.1914  | 0.3305  |
| Male    | 34                | 257                   | 0.6149 | 0.3680–1.0275  | 0.0634  |
| DM      | 51                | 257                   | 6.8718 | 1.7083–27.6414 | 0.0066* |
| HTN     | 35                | 152                   | 2.1212 | 1.2451–3.6137  | 0.0057* |
| Smoker  | 22                | 175                   | 0.6989 | 0.4200–1.1628  | 0.1678  |
| CVA     | 9                 | 47                    | 1.2236 | 0.6332–2.3647  | 0.6     |
| IHD     | 32                | 125                   | 2.2712 | 1.3612–3.7895  | 0.0017* |
| HLD     | 12                | 41                    | 1.8665 | 1.0509–3.3152  | 0.0332* |
| CKD     | 7                 | 19                    | 2.1363 | 1.0731–4.2528  | 0.0307* |

DM, diabetes mellitus; HTN, hypertension; CVA, cerebrovascular accident; IHD, ischemic heart; HLD, hyperlipidemia; CKD, chronic kidney disease; CI, confidence interval; RR, relative risk. *p* = two-tailed *t* test. \* Statistically significant.

## Results

391 patients were included in the study. The mean age was  $58 \pm 10$  years old, with male a predominance of 76% (296 patients). The risk factors were diabetes in 79% (308 patients), hypertension (HTN) in 48% (187 patients), smoking in 50% (197 patients), stroke in 14% (56 patients), ischemic heart disease in 40% (157 patients), hyperlipidemia (HLD) in 14% (53 patients), and chronic renal failure in 7% (26 patients). A majority of the patients (*n* = 211, 54%) presented with chronic limb threatening ischemia, which included 134 patients with rest pain (34%) and 79 patients with tissue loss or gangrene (20%). Table 1 shows the demographics of this cohort of patients and procedure indications.

Femoro-popliteal bypasses were the most frequently performed procedures accounting for 164 (42%) procedures. Other bypasses performed included inflow procedures like aorto-femoral and ilio-femoral bypasses (20%), tibial bypasses (10%), and extra-anatomic bypasses (5.8%). Synthetic conduits were used above the knee. All below knee bypasses were performed with a vein conduit with the exception of 10 patients (2.6%) without sufficient autogenous conduit options, and those underwent a composite sequential bypass. Table 2 shows all procedures performed, including nonbypass procedures, and types of conduits used.

Wound infections occurred in 53 (14%) patients. All wound infections developed in the peri-operative period within 30 days of the index operation. Wound hematomas preceded wound infections in 6 patients. Wound cultures most commonly grew *Staphylococcus aureus* (*n* = 25, 47%), and other organisms isolated included *Pseudo-*

**Table 4.** Univariate ORs for wound infection comparing different risk factors

|         | OR     | 95% CI         | p value |
|---------|--------|----------------|---------|
| Age >65 | 1.3548 | 0.7313–2.5099  | 0.3344  |
| Male    | 0.564  | 0.3051–1.0426  | 0.0677  |
| DM      | 8.037  | 1.9142–33.7439 | 0.0044* |
| HTN     | 2.3794 | 1.2960–4.3684  | 0.0052* |
| Smoker  | 0.661  | 0.3677–1.1884  | 0.1666  |
| CVA     | 1.2664 | 0.5803–2.7639  | 0.553   |
| IHD     | 2.5966 | 1.4349–4.6987  | 0.0016* |
| HLD     | 2.1202 | 1.0305–4.3620  | 0.0412* |
| CKD     | 2.5549 | 1.0181–6.4115  | 0.0457* |

DM, diabetes mellitus; HTN, hypertension; CVA, cerebrovascular accident; IHD, ischemic heart; HLD, hyperlipidemia; CKD, chronic kidney disease; CI, confidence interval. *p* = two-tailed *t* test. \* Statistically significant.

*monas* in 18 (34%), MRSA and *Escherichia coli* both in 7 (13%), *Candida albicans* in 5 (9%), *Proteus mirabilis* in 4 (8%), and *Enterococcus faecalis* in 3 (7%) patients. Wound infections were treated with culture-guided intravenous antibiotics and local wound care and debridement. Only four cases required extensive wound debridement and coverage of the vascular graft with a pedicle rotational sartorius muscle flap. Three cases required removal of the vascular graft after deep-seated wound infection, pseudoaneurysm, and secondary hemorrhage. These patients eventually required above-knee amputation, and 1 patient died after sepsis and renal failure despite optimal infection source control.

**Table 5.** Multivariate logistic regression comparing different risk factors for wound infection

| Infection | OR    | Standard error | z      | p value | 95% CI       |
|-----------|-------|----------------|--------|---------|--------------|
| Age >65   | 1.024 | 0.014          | 1.710  | 0.087   | 0.997–1.052  |
| Male      | 0.726 | 0.258          | −0.900 | 0.368   | 0.361–1.458  |
| DM        | 8.585 | 6.371          | 2.900  | 0.004*  | 2.005–36.764 |
| HTN       | 1.574 | 0.553          | 1.290  | 0.196   | 0.791–3.133  |
| Smoker    | 0.928 | 0.324          | −0.220 | 0.830   | 0.468–1.839  |
| CVA       | 0.745 | 0.338          | −0.650 | 0.517   | 0.306–1.812  |
| IHD       | 1.773 | 0.606          | 1.680  | 0.094   | 0.907–3.466  |
| HLD       | 1.444 | 0.586          | 0.910  | 0.365   | 0.652–3.201  |
| CKD       | 1.652 | 0.846          | 0.980  | 0.327   | 0.606–4.506  |
| _cons     | 0.004 | 0.005          | −4.760 | 0.000   | 0.000–0.039  |

DM, diabetes mellitus; HTN, hypertension; CVA, cerebrovascular accident; IHD, ischemic heart; HLD, hyperlipidemia; CKD, chronic kidney disease; CI, confidence interval. *p* = two-tailed *t* test. \* Statistically significant.

A comparison of risk factors was performed in the group with wound infections (*n* = 53) and the group without wound infections (*n* = 338). Significant associations were detected between wound infection and diabetes, HTN, ischemic heart disease, HLD, and chronic renal failure. Diabetes had the highest OR (OR 8.04, 95% CI: 1.9142–33.7439, *p* = 0.0044) for wound infection development. Other significant risks had lower ORs and included HTN (OR 2.38, 95% CI: 1.2960–4.3684, *p* = 0.0052), ischemic heart disease (OR 2.30, 95% CI: 1.4349–4.6987, *p* = 0.0016), HLD (OR 2.12, 95% CI: 1.0305–4.3620, *p* = 0.0412), and chronic renal failure (OR 2.55, 95% CI: 1.0181–6.4115, *p* = 0.0457). Risk factors that did not reach significance included age greater than 65 years, male gender, smoking, and prior history of stroke. ORs, relative risk values, and 95% CIs of all proposed risk factors are summarized in Tables 3 and 4. Multivariate logistic regression identified only diabetes as a significant risk factor for wound infection when controlling for other variables (Table 5).

## Discussion

Szilagyi et al. [3] was the first to develop the classification of vascular wound infections in 1972. Wound infections were classified into three types, involvement of the overlying skin (type I), skin and subcutaneous tissue (type II), and skin, subcutaneous tissue, and the underlying graft (type III). The most common source of infection is inoculation at the time of the procedure. Josephs et al. [5] reported that wound infection was due to both diabetes mellitus and an open lesion on the ipsilateral limb. An

infected ipsilateral lymph node was not a risk factor for post-operative vascular wound infection. They found 11% infected lymph nodes, of which only 4.5% developed groins wound infection.

The most commonly reported pathogens responsible for wound infection were *S. aureus*, coagulase-negative staphylococcus (late infection), and methicillin-resistant staphylococci. Less frequently encountered organisms are Gram-negative bacteria, like *E. coli* and multiresistant Gram-negative organisms [6, 7]. Newington et al. [8] reported that groin infection is related to colonization by perineal organisms, especially *Pseudomonas aeruginosa* and *Proteus* species in 8.5% of cases.

Reported risk factors for the development of wound infections include age, obesity, increased length of hospital stay, diabetes mellitus, renal failure, smoking, and type of incision [8–10]. Increased susceptibility to infection and impaired healing of skin wounds after the sixth decade of life is due to alteration in the immune system function, physiologic changes in aging organs, and the presence of chronic diseases in the elderly population. After the age of 70 years, there is a 2.3-fold increased risk of surgical wound infections (OR = 2.3, 95% CI: 1.1–4.5). Procedure duration more than 2 h has 3.1-fold increased risk of surgical wound infections (OR = 3.1, 95% CI: 1.2–7.7) [9]. Inpatient length of stay and the rate of wound infections are positively correlated. A rate of infection of 1.2% with 1-day hospitalization increases to 3.4% after 2 weeks of hospital stay [11].

In diabetic patients, there is a direct relationship between increasing HbA1c and glucose levels in the immediate post-operative period and with wound infections [12–14]. Obesity and the presence of a large abdominal

**Table 6.** Comparison of procedural outcomes in other studies with our patient cohort

| Author [reference]      | <i>n</i> | Vascular bypasses, <i>n</i> | Graft vein, <i>n</i> | Graft synthetic, <i>n</i> | DM, <i>n</i> (%) | Wound infection, <i>n</i> (%) | Graft infection, <i>n</i> (%) |
|-------------------------|----------|-----------------------------|----------------------|---------------------------|------------------|-------------------------------|-------------------------------|
| Ascer et al. [24]       | 62       | 68                          |                      | 68                        | 37 (60)          | 1 (1)                         | 1 (1)                         |
| Misare et al. [25]      | 93       | 101                         | 101                  |                           | 93 (92)          | 3 (3)                         | 0                             |
| Misare et al. [25]      | 99       | 105                         | 105                  |                           | 78 (74)          | 3 (3)                         | 0                             |
| Faries et al. [26]      | 454      | 520                         | 520                  |                           | 385 (85)         | 10 (2)                        | 2 (0.3)                       |
| Lantis et al. [27]      | 60       | 78                          | 78                   |                           | 50 (83)          | 4 (5)                         | 0                             |
| Lantis et al. [27]      | 37       | 41                          | 41                   |                           | 28 (76)          | 5 (12)                        | 0                             |
| Kreienberg et al. [28]  | 105      | 48                          |                      | 48                        | 20 (44)          | 2 (4)                         | 2 (4)                         |
| Kreienberg et al. [28]  | 105      | 59                          |                      | 59                        | 32 (53)          | 3 (5)                         | 6 (10)                        |
| Whittemore et al. [29]  | 240      | 300                         |                      | 300                       | 118 (39)         | 8 (3)                         | 0                             |
| Johnson et al. [30]     | 53       | 69                          | 62                   | 5                         | 43 (81)          | 6 (9)                         | 2 (3)                         |
| Belkin et al. [31]      | 661      | 767                         | 767                  |                           | 332 (50)         | 56 (7)                        | 0                             |
| Total                   | 1,814    | 1,987                       | 1,573                | 412                       | 1,086 (60)       | 97 (5)                        | 12 (0.6)                      |
| AlFawaz (present study) | 391      | 307                         | 108                  | 189                       | 308 (79)         | 53 (14)                       | 4 (1)                         |

DM, diabetes mellitus.

pannus may lead to the incision being buried underneath, with excessive moisture, leading to a secondary infection.

Incision type and location play a role in the rate of wound infections in addition to other technical considerations at the time of the procedure. Vertical inguinal incisions are perpendicular to the lines of stress, cut across the skin creases, tend to gap with hip flexion, resulting in poor wound healing. Supra-inguinal incisions parallel to the lines of stress provide adequate exposure of the femoral artery and may lead to a lower rate of wound infections [15]. Vascular wound infections are more frequent with inguinal incisions than other locations. This is evident when comparing the infection rate in aorto-bifemoral bypasses (1.6–3.2%) with aorto-iliac bypasses (0.7–0.9%) [3]. Subcutaneously tunneled (extra-anatomical) vascular conduit has a higher risk of wound infection, 43% (9/21) compared to the sub-sartorial (anatomical) graft, 8% (3/26) in-patient with renal failure [16].

Prophylactic peri-operative antibiotics were used in all of our patients to mitigate infection risk. In one study, wound infection risk was reduced from 30% to 14% with prophylactic antibiotics [17]. Multiple dose antibiotics region is recommended, although Kester et al. [18, 19] showed that a single-dose teicoplanin had similar efficacy to a three-dose regimen of cephradine and metronidazole.

We ensured all patients were shaved immediately prior to incision. This has a lower wound infection rate when compared to patients who shaved within 24 h of surgery

(3.1% vs. 7.1%). Showering with disinfectant soap prior to surgery was within our protocol. Disinfectant soap lowered the risk of infection when compared to patients who did not use it (1.3% vs. 2.3%) [11]. The choice of disinfectant favors chlorhexidine over povidone iodine with a 9-fold reduction in bacterial count versus 1.3-fold [20, 21].

Wound infections usually present early in the peri-operative period. The infection presents with local signs of inflammation. Cellulitis, inflammatory mass, sinus tract, and anastomotic pseudoaneurysm are all signs of extracavitary infection [22]. Wound infection is usually apparent and does not require extensive diagnostic tests unless when associated graft infection is highly suspected. Ultrasonography, computerized tomography, magnetic resonance imaging, angiography, and nuclear medicine imaging are all tools used to confirm the presence of serious sequelae of wound infection (i.e., graft infection) [22]. When the graft is infected, necessitating radical excision with extra-anatomical bypass, the risk of mortality is 25–75% and the limb loss is 35–79% [23].

The data compiled in Table 6 compares our findings with other studies in the literature examining vascular wound infections, incidence of graft infections, and prevalence of diabetes in the studied populations [24–31]. Our data show a patient population with a higher risk and incidence of wound infection despite utilizing all methods to mitigate this risk. This further illustrates that the presence of several risk factors, which was highly prevalent in



our patient population, increases the risk of wound infection after vascular surgery.

Limitations of our study include those common to retrospective data analysis design. Some variables that are considered significantly associated with wound infection were not available for collection. These include patient body mass index and procedural times. There was no specific definition of wound infection that was used, and the diagnosis was either by documentation of the diagnosis alone or inference by the use of antibiotics and debridement for the surgical wound. Our patient population was relatively young, and the age range was narrow. This may have skewed the results toward the null hypothesis.

## Conclusion

Diabetes, HTN, ischemic heart disease, HLD, and chronic renal failure were all found to have a significant association with post-operative wound infections. Age over 65 years, male gender, smoking, and history of stroke were not significantly associated with the development of vascular wound infections. Anticipation of wound complications in patients with these risk factors may aid in early diagnosis and treatment.

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All contributors fulfilled ICMJE criteria and were included in the authorship.

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## Statement of Ethics

Chart review was performed, and patient data were de-identified. Original data with patient identifiers were discarded. The study qualified for exempt status and individual patient consent was not required.

## Conflict of Interest Statement

All authors listed on this manuscript have no affiliation with, or involvement in, any organization or entity with financial or nonfinancial interests in the subject matter or materials discussed in the manuscript.

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## Author Contributions

All authors listed on the manuscript contributed to data collection, data analysis, manuscript writing, and critical review.

## Data Availability Statement

The data that support the findings of this study are not publicly available as they contain information that could compromise the privacy of research participants but are available from the corresponding author Abdullah A. AlFawaz upon reasonable request.

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