IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 23, Issue 3 Ser. 6 (March. 2024), PP 30-36
www.iosrjournals.org

Surgical Factors In Formation Of Tourniquet Site Blisters For Lower Limb Procedures In Awka, Nigeria.

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Abstract
Introduction:
Blistering following lower limb procedures, including arthroplasty, arises from multifactorial causes categorized into patient and surgical factors. Patient factors involve obesity, age, vascular conditions, and diseases impacting wound healing, while surgical factors encompass tourniquet time, dressings, and skin preparation. Skin blistering, characterized by epidermal separation from the dermal layer, is a potential complication of total knee arthroplasty, though significant blistering remains rare despite its reported incidence.
Methodology:
A study involving 46 participants undergoing lower limb surgeries investigated the influence of surgical factors on tourniquet site blister development. The cohort had diverse demographics, with a mean age of 64.37 years and a predominance of females. Various lower limb surgeries, primarily knee arthroplasty, were performed under specific tourniquet pressures and durations. A notable portion (41.3%) developed tourniquet site blisters, predominantly mild in severity, with occurrences immediately post-procedure or within 24 hours.
Results:
Factors associated with blister presence included age, weight, mid-thigh circumference, tourniquet pressure, and duration of surgery. Logistic regression analysis highlighted weight, mid-thigh circumference, tourniquet pressure, and surgical duration as significant predictors of blister development, with younger age showing a trend. Multivariate analysis emphasized larger mid-thigh circumferences and longer surgical durations as significant predictors, while age and tourniquet pressure exhibited limited independent predictive power.
Conclusion:
Large mid-thigh circumferences and prolonged tourniquet application duration significantly influence tourniquet blister formation in lower limb procedures. While tourniquet pressure,as a single variable, it lacked significance when combined with other variables. Surgeons should consider these surgical factors to mitigate blister-related complications in lower limb surgeries involving tourniquet application.

Date of Submission: 20-03-2024 Date of Acceptance: 30-03-2024

I. Introduction

The causes of blistering in patients following lower limb procedures, including arthroplasty is likely to be multifactorial and can be divided into patient factors and surgical factors. The patient factors could include obesity, increasing age, vascular, autoimmune conditions and any disease that predisposes to poor wound healing including smoking, alcohol, diabetes and hypertension. The surgical factors could include increasing tourniquet time, surgical dressings and skin preparation.[1]

In 1986, Shelton defined skin blisters as bullae, signifying areas of epidermal necrosis characterized by the separation of the stratified squamous cell layer from the underlying vascular dermal layer due to tissue edema fluid. Total knee arthroplasty is a commonplace procedure in the UK, with patients facing a lifetime risk of requiring total knee arthroplasty up to 10%.[2,18] Skin blistering, potential complication following trauma, has been reported in as high as 35% of patients, with causes being multifactorial, including the use of dressings and tourniquets. Despite this, significant blistering associated with arthroplasty remains rare.[3]

Skin blistering is essentially a fluid-filled sac beneath the epidermis, resulting from the separation of the epidermis from the underlying dermis due to frictional forces. The formation of blisters compromises the protective skin barrier, increasing the risk of developing a periprosthetic joint infection.[4] While intact blisters are sterile, studies have linked their rupture to an increased risk of infections.[5,17]

The etiopathology of these blisters appears to stem from excessive stress at the skin level, leading to increased pressure at the dermo-epidermal junction. Histologically, blistering occurs due to the separation of the

epidermis from the vascular dermis, accompanied by the build-up of edema fluid.[6] Blisters can be classified as haemorrhagic or clear, with haemorrhagic blisters representing more significant soft tissue injuries and taking longer to heal.

Studies have highlighted the association between wound dressings and blistering rates, with factors such as tape application and dressing type playing a role during Intra-operative dressings like Ioban have been suggested to contribute to blister development due to shearing at the dermo-epidermal junction.[7]Also, the use of pneumatic tourniquets in arthroplasty surgery is common but has been hypothesized to increase shearing forces when released after dressing application. Some studies recommend releasing the tourniquet before applying the dressing to reduce blister incidence.[8]

The pneumatic tourniquet is extensively employed in surgeries involving extremities to establish a bloodless field and aid in dissection. However, it is crucial to recognize the potential complications associated with its use and understanding the principles of tourniquet application can help minimize these issues. Complications linked to the use of a pneumatic tourniquet can be categorized as systemic and local. In knee arthroplasty surgery, a tourniquet is frequently utilized to enhance visualization, streamline operative time, minimize blood loss, and create optimal conditions for cementing. A higher tourniquet pressure ensures the reliable function of the tourniquet; however, it may lead to a greater incidence of complications .[9,10,17] These complications are commonly related to the duration of its use and the inflation pressure. While a lower tourniquet pressure is safer, it may not provide a bloodless operative field. However, more consensus is needed regarding the optimal target inflation pressure.[16] Nonetheless, a hypothesis suggests that releasing the tourniquet post-dressing application might escalate shearing forces between the dermis and epidermis, owing to external pressure, while concurrently compromising vascular supply to the dermis. Consequently, specific authors advocate for releasing the tourniquet before applying the dressing.[11,19]

Systemic complications encompass effects on the cardiovascular system, including a transient rise in central venous pressure and systolic blood pressure. [9] Metabolic changes are also observed, with alterations in arterial pH, PaO2, PaCO2, lactic acid, and potassium levels after release, with the extent largely determined by the duration of ischemia time[10,12]. Additionally, core body temperature experiences an increase during tourniquet inflation and a subsequent decrease following tourniquet release.[12] The application of an extremity tourniquet can impact the kinetics of drugs, leading to a decrease in the concentration and penetration of intravenous perioperative medications.

The management of blisters remains controversial, with the fluid within blisters acting as a sterile biological dressing for deeper tissues. Although de-roofing blisters is a consideration, there is no clear evidence on the optimal approach. If de-roofed, suggested dressings include topical silver sulfadiazine, although conclusive evidence supporting this practice is lacking.[1,20,21,22] Overall, the prevention and management of blisters in arthroplasty patients is a complex issue that requires consideration of multiple factors including patient characteristics, surgical techniques, and wound dressings to minimize the risk of complications and optimize patient outcomes.

This study aims at investigating the surgical factors in the formation of tourniquet site blisters following lower limb procedures.

II. Methodology:

All the patients undergoing primary and revision arthroplasties over a period of 2 years were recruited into this study. They had their surgeries under pneumatic tourniquet placed equidistant above the knee avoiding the point of commencement of skin incision above the knee joint.

With patient supine under spinal and epidural anesthesia, soft band was applied over the thigh and the tourniquet cuff was placed at a distance between 25 to 30 cm above the knee and secured to machine. There were skin preparations and sterile draping.

The lower limbs were exsanguinated with Esmarch bandage and the tourniquet inflated to set pressures of between 280 and 360. The fatter the patient with a higher thigh circumference, the higher the pressure was set.

The tourniquet cuff was deflated and removed immediately after placing sterile dressing and the site of application was observed for blisters. The observations were done immediately after surgery, 1hr after surgery and after 24hours.

The blisters were measured and classified according to size in its longest or widest margin.

They were grouped as less than one centimeter (<1cm), between one centimeter and five centimeters (1-5cm), above five centimeters (>5cm).

The findings were analyzed using the SPSS version 16.

III. Result

The study enrolled 46 participants undergoing lower limb surgeries to investigate the influence of surgical factors on the development of tourniquet site blisters

Table 1 Socio-Demographics

	Mean (SD) Median (IQR) N	**Range %**
Age	64.37 ± 9.1	26.0-83.0
Weight (kg)	81.0 (72.25-103.0)	56.0-145.0
Mid-thigh circumference	60.0 (56.0-72.0)	53.0-102.0
Gender		
Female	42	91.3
Male	4	8.7
Occupation		
Business	17	37
Retired	12	26.1
Civil Servant	6	13
None	11	23.9
Religion		
Christian	46	100

Table 2 Surgical and Clinical Characteristics

	Frequency Median	**Percentage Range**
DIAGNOSIS		
Severe Right Knee Osteo Arthritis	23	50
Severe Left Knee Osteo Arthritis	20	43.5
Failed Left TKR	1	2.2
Failed Left Infected TKR	1	2.2
Failed Primary Left TKR	1	2.2
SURGICAL PROCEDURE		
Right TKR	23	50
Left TKR	20	43.5
Left Revision TKR	1	2.2
Removal Of Implant, Debridement + Washout + Implantation of Spacer	1	2.2
Revision TKR	1	2.2
Torniquet Pressure	310.0 (300.0-320.0)	280.0-350.0
Duration of Surgery	122.0 (103.5-142.25)	67.0-255.0
BLISTERS		
Presence Of Blisters		
No	27	58.7
Yes	19	41.3
Mild Blisters (Less than 1cm)		
No	32	69.6
Yes	14	30.4
Moderate Blisters (1 to 5cm)		
No	42	91.3
Yes	4	8.7

Severe Blisters (Greater than 5cm)		
No	45	97.8
Yes	1	2.2
Blisters occurring immediately after procedure		
No	28	60.9
Yes	18	39.1
Blisters occurring one hour after procedure		
No	45	97.8
Yes	1	2.2
Blisters occurring 24 hours after procedure		
No	37	80.4
Yes	9	19.6
Blister requiring dressing		
No	46	100
MANAGEMENT PROTOCOL		
Patient on antibiotics		
Yes	44	95.7
No	2	4.3
On antibiotics before surgery		
No	36	78.3
Yes	10	21.7
On antibiotics after surgery		
Yes	45	97.8
No	1	2.2

Table 3 Factors associated with presence of Blisters

	No (n = 27)	**Yes (n = 19)**	**p-value**
Age	66.59 ± 6.69	61.21 ± 11.16	0.047**
Weight	74.0 (68.5-82.5)	103.0 (84.5-125.5)	0.0001**
Mid-thigh circumference	58.0 (55.0-60.75)	72.0 (65.0-86.0)	0.0001**
Gender			
Female	24 (88.9)	18 (94.7)	
Male	3 (11.1)	1 (5.3)	0.872
Diagnosis			
Failed left infected TKR	0 (0.0)	1 (5.3)	
Failed left TKR	0 (0.0)	1 (5.3)	0.322
Failed primary left TKR	0 (0.0)	1 (5.3)	
Severe left knee osteo arthritis	12 (44.4)	8 (42.1)	
Severe right knee osteo arthritis	15 (55.6)	8 (42.1)	
Tourniquet pressure	310.0 (300.0-315.0)	320.0 (320.0-335.0)	0.0001**
Duration of surgery (minutes)	111.0 (97.0-130.0)	140.0 (121.5-176.0)	0.002**
MANAGEMENT PROTOCOL			
On antibiotics			
No	2 (7.4)	0 (0.0)	

Yes	25 (92.6)	19 (100.0)	0.632
On antibiotics before surgery			
No	22 (81.5)	14 (73.7)	
Yes	5 (18.5)	5 (26.3)	0.788
On antibiotics after surgery			
No	1 (3.7)	0 (0.0)	
Yes	26 (96.3)	19 (100.0)	0.999
** Statistically significant			

Table 4 Logistic Regression Analysis to Determine the Predictive Variables of Blisters among Patient who Underwent Knee Arthroplasty

Predictive Variables	Odds Ratio	p-value	95% Confidence Interval (CI)
Age	0.922	0.0707	0.845 - 1.007
Weight (kg)	1.068	0.0013**	1.026 - 1.111
Mid-thigh circumference	1.151	0.0015**	1.056 - 1.256
Tourniquet pressure	1.093	0.0033**	1.03 - 1.16
Duration of surgery (minutes)	1.033	0.0069**	1.009 - 1.057
** Statistically significant			

Table 5 Multiple Logistic Regression Analysis to Determine the Predictive Variables of Blisters among Patients Who Underwent Knee Arthroplasty with Tourniquet.

	Odds Ratio	p-value	95% CI
Age	0.953	0.3073	0.869 - 1.045
Mid-thigh circumference	1.15	0.0213**	1.021 - 1.295
Tourniquet pressure	1.054	0.2141	0.97 - 1.146
Duration of Surgery (minutes)	1.027	0.0369**	1.002 - 1.053

IV. Discussion

The study enrolled 46 participants undergoing lower limb surgeries to investigate the influence of surgical factors on the development of tourniquet site blisters. The socio-demographic profile revealed a mean age of 64.37 years (SD ± 9.1), ranging from 26.0 to 83.0 years, with a median of 64.0 years and an interquartile range (IQR) of 56.0-72.0 years. Participants exhibited a mean weight of 81.0 kg (median: 81.0 kg, IQR: 72.25-103.0 kg) and a mean mid-thigh circumference of 60.0 cm (median: 60.0 cm, IQR: 56.0-72.0 cm). The majority were female (91.3%), and diverse occupations were represented, including business (37%), retired individuals (26.1%), civil servants (13%), and those with no specified occupation (23.9%). All participants identified as Christian. These socio-demographic details set the stage for a comprehensive exploration of surgical factors associated with tourniquet site blister development in this cohort.

The study cohort (n=46) underwent various lower limb surgeries, with primary diagnoses including 50% (n=23) with severe right knee osteoarthritis and 43.5% (n=20) with severe left knee osteoarthritis. Additional diagnoses comprised failed left TKR (2.2%, n=1), failed left infected TKR (2.2%, n=1), and failed primary left TKR (2.2%, n=1). Surgical procedures involved right TKR (50%, n=23), left TKR (43.5%, n=20), and other interventions, each accounting for 2.2% (n=1).

Tourniquet application during surgeries was characterized by a median pressure of 310.0 mmHg (IQR: 300.0-320.0 mmHg) and a duration ranging from 67.0 to 255.0 minutes, with a median duration of 122.0 minutes (IQR: 103.5-142.25 minutes).

Among the participants, 41.3% (n=19) developed tourniquet site blisters. The severity distribution included mild blisters (30.4%, n=14), moderate blisters (8.7%, n=4), and severe blisters (2.2%, n=1). Blisters manifested immediately after the procedure in 39.1% (n=18) of cases, one hour after in 2.2% (n=1), and 24 hours after in 19.6% (n=9). All participants requiring blister dressing constituted 100% (n=46), providing a comprehensive overview of the blister-related outcomes.

The management protocol encompassed antibiotic administration, with 95.7% (n=44) receiving antibiotics, 78.3% (n=36) not receiving antibiotics before surgery, and 97.8% (n=45) receiving antibiotics after surgery.

In examining factors associated with the presence of tourniquet site blisters in our cohort of 46 participants undergoing lower limb surgeries, several key observations emerged. Notably, age exhibited a statistically significant difference between individuals with and without blisters, with those developing blisters being younger (61.21 ± 11.16) compared to their counterparts (66.59 ± 6.69) (p=0.047).

Furthermore, weight and mid-thigh circumference demonstrated significant associations with blister occurrence. Participants who developed blisters had a notably higher weight (103.0, IQR: 84.5-125.5) compared to those without blisters (74.0, IQR: 68.5-82.5) (p=0.0001). Similarly, individuals with larger mid-thigh circumferences (72.0, IQR: 65.0-86.0) were more prone to blister development than those with smaller circumferences (58.0, IQR: 55.0-60.75) (p=0.0001).

Gender distribution did not exhibit a significant association with blister presence (p=0.872), with 94.7% of females and 5.3% of males having blisters. Likewise, specific diagnoses, including failed left infected TKR, failed left TKR, failed primary left TKR, severe left knee osteoarthritis, and severe right knee osteoarthritis, did not show significant associations with blister development.

Regarding surgical and procedural variables, both tourniquet pressure and the duration of surgery displayed statistically significant associations with blister occurrence. Higher tourniquet pressure (320.0, IQR: 320.0-335.0) was observed in participants with blisters compared to those without blisters (310.0, IQR: 300.0-315.0) (p=0.0001). Additionally, a longer duration of surgery (140.0, IQR: 121.5-176.0 minutes) was significantly associated with blister development compared to a shorter duration (111.0, IQR: 97.0-130.0 minutes) (p=0.002).

Interestingly, the administration of antibiotics, either before or after surgery, did not exhibit significant associations with blister presence (p>0.05).

In our logistic regression analysis to discern predictive variables associated with tourniquet site blister development in patients undergoing knee arthroplasty, several noteworthy associations emerged. The analysis considered age, weight, mid-thigh circumference, tourniquet pressure, and duration of surgery as potential predictors.

For age, although the association did not reach statistical significance (p=0.0707), a trend suggested that younger individuals may have a reduced likelihood of developing blisters, as indicated by the odds ratio of 0.922 (95% CI: 0.845 - 1.007).

Weight demonstrated a significant association, with an odds ratio of 1.068 (p=0.0013), revealing that an increase in weight corresponded to a higher likelihood of blister development. Similarly, mid-thigh circumference showed a significant association, with an odds ratio of 1.151 (p=0.0015), indicating that individuals with larger mid-thigh circumferences were more prone to experiencing blisters.[25]

Tourniquet pressure exhibited a significant association, with an odds ratio of 1.093 (p=0.0033). Elevated tourniquet pressure was linked to an increased likelihood of blister development' This is in agreement with the findings by Pinsornsak et al which showed that higher tourniquet pressures which are 150mmhg above the systolic pressure have higher complications than those that are less.[23] Likewise, the duration of surgery demonstrated a statistically significant association, with an odds ratio of 1.033 (p=0.0069), suggesting that longer surgical durations were associated with higher odds of developing blisters This is in keeping with the findings of Olivercrona et al which showed that tourniquet duration that exceeds 100minutes isassociated with complications.[24]

In our multivariate logistic regression analysis aimed at discerning predictive variables for the development of tourniquet site blisters among patients undergoing knee arthroplasty, we considered age, mid-thigh circumference, tourniquet pressure, and duration of surgery as potential predictors while accounting for potential confounding variables.

Notably, larger mid-thigh circumferences emerged as a significant predictor (odds ratio = 1.15, p=0.0213), indicating an increased likelihood of blister occurrence in individuals with greater mid-thigh measurements.[25,26] Additionally, a longer duration of surgery was found to be significantly associated with a

higher risk of blister development (odds ratio = 1.027, p=0.0369), underscoring its importance in predicting outcomes even in the presence of potential confounding variables.

Conversely, age and tourniquet pressure did not exhibit statistically significant associations (odds ratio for age = 0.953, p=0.3073; odds ratio for tourniquet pressure = 1.054, p=0.2141), suggesting limited independent predictive power in this context.

V. Conclusion:

Patients with large mid-thigh circumferences have a significant association and predictive value for tourniquet blister formation following lower limb procedures. The duration of tourniquet application also has a direct influence and predictive value on the formation of tourniquet site blisters. However, tourniquet pressure, though has an association with blister formation when considered alone but with multivariate analysis, it turned out not significant. These are surgical factors in the formation of blisters and should guide the surgeon when performing lower limb surgeries with the tourniquet.

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