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Incidence and factors Associated with Infection on Patients SIGN Nail Done for Long Bone Fractures in Tibebeghion Specialized Hospital, Bahir Dar, Ethiopia

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Incidence and factors associated with infection on patients SIGN nail done for long bone fractures in TibebeGhion Specialized Hospital, Bahir Dar, Ethiopia

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Study	Study design	Retrospective cross sectional
	Study project	Surgical site infection after intramedullary SIGN nail
	Study area	TGSH, department of orthopedic surgery, Bahrdar, Ethiopia

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Abstract

BACKGROUND: Infections has been associated with significant morbidity, mortality and increased medical cost after SIGN nailing. It complicates up to 1-3% closed and 10 % of open fractures, which can rise up to 50% in severe forms. long bone fractures are one of the most common limb fractures representing a significant portion of the trauma workload. Most of them need surgical treatment, including SIGN nail which is widely accepted and practiced in Ethiopia.

OBJECTIVE: To estimate the incidence and to identify factors associated with surgical site infection after intramedullary SIGN nailing of long bone fractures in patients operated with a SIGN nail in TGSH.

METHODS AND MATERIALS: The study was conducted using a retrospective cross-sectional study in patients who were admitted and operated with SIGN nail from January 2018 to September 30/2020 who fulfill the inclusion criteria. Cases with SIGN nail were reviewed and cases with SSI were analyzed in particular. The data was entered and analyzed using SPSS windows version 23 software. Descriptive statistics like frequency tables and descriptive summaries were used to describe the variables. Binary logistic regression model was used to analyze the association between variables. Bi variable and multivariable logistic regression analysis were used and the results were presented in tables and charts. Odds ratio (OR) was used to compare associations between dependent and independent variables.

Results: The overall incidence of infection was 5.2 %. It varies with the nature and severity of injury which is 10.7% in open fractures and 1.7% in closed fractures. In open injuries infection rate increases as severity increases accounting 1.33%,2.67% and 10.67% for grade I, grade II and grade IIIA fractures respectively.

Conclusion and Recommendation

The present study showed overall incidence of infection is comparable to LMICs but higher than developed countries. Complex, open fractures whose surgeries were done early and external fixator use were found to be associated factors for infection. So, more attention should be given to patients with long bone fractures on SIGN nails for complaints around the surgical wound and we recommend further study on this topic.

Keywords: long bone fracture, associated factor, SIGN, surgical site infection.

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ACRONYMS:

BDU	Bahir Dar University
CDC	Center for disease control
CI	95% confidence interval
DM	Diabetes mellites
E.C	Ethiopian Calendar
EX FIX	External fixator
G.C	Gregorian Calendar
GP	General practitioner
HIV	Human immunodeficiency virus
HTN	Hypertension
IMN	Intramedullary nail
IRB	Institutional Review Board
LMICs	Low- and middle-income countries
NHSN	National health service network
PI	Principal Investigator
R	Resident
RTA	Road traffic accident
SOSD	SIGN online surgical database
SPSS	Statistical Package for the Social Sciences
SSI	Surgical site infection
TGSH	TibebeGhion specialized Hospital

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1. Introduction

1.1 Background

Every year around 20-50 million people are injured due to road traffic accidents. Developing countries account for the majority of these injuries where two billion people do not have access to modern surgical care. The majority of these injuries include long bone fractures [1].

Around 5.8 million people die annually as a result of injuries. Over 90 % of these fatal injuries occur in low- and middle-income countries (LMIC) like Ethiopia. For one death from injury 3–10 more people will survive from injury and develop a permanent disability which is a devastating and a costly outcome of the society. In young people between the ages of 10 and 24 years around 97 % of deaths occur in LMIC, over 40 % of deaths are related to injuries, and road traffic injuries are the most common cause followed by a fall down accidents. Nowadays the global burden of injuries is increasing rapidly, and is almost entirely in LMICs. By 2030 the World Health Organization (WHO) expects road traffic accidents to be increased from the 9th to the 5th leading cause of all deaths worldwide [2]. Many of these injuries require surgical care which may not be available to patients in many developing countries where it is the leading cause of death between 5 and 45 years old. And, the best treatment for a long bone open and closed diaphyseal fracture is the surgical fixation with an intramedullary nail [1, 3].

An intramedullary nail (an intramedullary rod), is a metal nail that is surgically inserted into the fractured bone. Intramedullary nails are used to straighten and hold fractures so that they can properly heal in their near original anatomic alignment [4]. Introduced by Gerhard Kutscher in 1939, intramedullary nailing remains to be the gold standard treatment choice for treating closed and many open long bone fractures. It is relatively simple, with less soft tissue damage and allows early weight bearing and return to work [3].

Low- and middle-income countries use a locked type intramedullary nailing donated by SIGN Fracture Care International, a-non-profit organization based in Washington state, Richland, USA, founded by Dr. Lewis G. Zirkle, Jr.in 1999. He has provided with training and SIGN equipment which do not require image intensifier and a fracture table unlike nails used in the developed world. Since January 2008, it has become possible to achieve interlocking nail insertion in Ethiopia (the birth of modern orthopedics), because of SIGN (Surgical Implant Generation Network program

[1]. Operations are being reported to the program office using the SIGN Online Surgical Database (SOSD) to replace every single SIGN nails used [5].

Long bones are longer than they are wide and include the femur, tibia, humerus, fibula, metatarsals, and phalanges These long bone fractures are most common in the young due to high energy injuries. More than two-fifth of these injuries occur in the lower limb of which tibia is the commonest site [6].

Open fractures are very common and life-threatening injuries which frequently involve the lower limb. It is a fracture in which disruption of the skin and underlying soft tissues result in a communication between the fracture or fracture hematoma and external environment. Open fractures are classified into three types based on the Gustilo and Anderson classification system from type I to III based on wound size, level of contamination and degree of injury [7].
Surgical site infections are defined according to the CDC-NHSN criteria and surveillance as the occurrence of infection within 12 months of surgery in patients with implant and within 30 days of surgery without implant in situ. Surgical site infection (SSI) related to IMN is considered a serious and difficult-to-treat complication, which may cause delayed healing and limb function loss or sometimes amputation. SSIs include superficial, deep and organ space infections; but, any infection reported at follow-up after SIGN is considered to be clinically significant and therefore did not differentiate between deep and superficial infections[8].
Open fractures are of special risk of SSI and certain precautions are important to decrease the development of SSIs. Initiation of immediate antibiotic Prophylaxis in open fractures is the most important factor to minimize these infections because there is a progressive rise in the infection rate with a delay in timing of initiation of prophylactic antibiotics. Hence, prophylactic antibiotic initiation within 3 hours of injury resulted in a lower infection rate (4.7%) relative to antibiotic delay greater than 3 hours (7.4%). Therefore , antibiotic timing has been shown to have an effect on the infection rate and it is recommended to provide as soon as possible after an open fracture [9].

Early debridement is also an important factor to reduce subsequent infections. Rather than the earlier recommendation of a “6 -hour rule” a 6 to 24-hour delay in the surgical debridement of open fractures allows better preoperative planning, better recognition of the severity of associated injuries and adequate clinical stabilization. Evidences shows that infection rates were

12.22% and 13.24%, in debridement's done before and after 6 hours of presentation respectively with no clinically significant difference. A recent systematic review concluded that strong support of "early surgical debridement" existed (within 24 hours) unless high energy and very contaminated [10].

Open fractures whose definitive surgeries done as early as 8 hours and immediate primary closure done as early as 6 hours had a lower infection rate as compared to delayed definitive surgery and late skin closures. So attempting immediate surgery and primary closure for all open fractures is a safe and efficient practice that does not increase the postoperative risk of infection [11, 12].

1.2 Statement of the problem

Risk of Surgical site infection following intramedullary nailing of closed fractures is similar to the general risk of infection after any orthopedic trauma procedure, but it is significantly higher in cases of open fractures which has been reported to be 4% -7% [12]. It is a serious and difficult-to-treat complication once occurred with high associated morbidity and mortality. It causes delayed fracture healing, limb function loss, amputation and associated socioeconomic dependency [3]. It also contributes to prolonged recovery, delayed discharge and increasing costs to both patients and the health care provider and society [13]. It is the most common and challenging complication, especially in open fractures occurring in up to 50% in severe forms. Septic complications need an early and aggressive approach with radical eradication of the septic focus. Unless an acute and minor infection which will be treated with minor surgical procedures and antibiotics giving a chance to leave implants in situ,most chronic infections usually demand prolonged, complex, multiple and multi-stage reconstructive measures of bones and soft tissues, including implant removal which has devastating psychological, social and economic cost of the patient, family and the community at large [14]. To address this, developed countries tried to increase the sterility of the operating field to reduce the number of microscopic particles in the air in the operating room with special types of ventilation, use image intensifier and well-trained staff to shorten surgery time with better subsequent follow up, and use modern wound closure techniques like antibiotic bead pouch and vacuum assisted closure. In most LMICs like Ethiopia, specifically in our set up, apart from the basic requirements for sterile surgery such as autoclaves, antiseptic wash, prophylactic antibiotics and wound care, research-based risk assessment, evidence-based prevention strategies and treatment solutions are not yet undertaken.

Less trained staff, delayed presentations, long operating time, sever spectrum of trauma with high prevalence of open fractures, lack of timely debridement and prophylactic antibiotics and lack of expensive equipment results in increased rate of surgical site infection [15].

1.3 Significance of the study:

Surgical site infection after intramedullary nailing of long bone fractures with SIGN implant is a common problem in our university hospital causing significant morbidity, long hospital stays and delayed rehabilitation. But there is no study which shows the incidence, associated factors contributing to it as well as prevention or treatment strategies of the problem. This study identifies major associated factors contributing to the development of surgical site infection and suggests preventive measures and create awareness of health professionals and policy makers about the magnitude of the problem and associated morbidity. We consider it is important to do research in our hospital to inform policy makers and multilateral donors in the university and the country at large to impact on the problems related to the implant. This was the first study to be done in our university hospital with this title and can be used as a baseline for other future studies.

2.Literature review

Surgical site infection is one of the common causes of post-operative morbidity & mortality. These infections contribute to prolonged time to recovery, delayed discharge and increasing economic costs to patients, family, health care system and society at large. They cause clinical and financial adverse effects for all surgical specialties; of course, certain surgical disciplines are at a particular challenge. In orthopedic surgeries, for instance, implant infection postoperatively makes it a septic focus and difficult to manage without the removal of this expensive and vital implant which causes bloodstream septicemia and consequent end organ damage or death unless the implant is removed [13].

In a large multi-center study done on risk factors for infection after 46,113 intramedullary nail operations in 58 low- and middle-income countries using the SOSD for registries from 2003 up to November 29, 2011 published in Octobe,2012; overall infection rate was 1.0 %. Specific fractures account 0.7 % for humerus,0.8 % for femur and 1.5 % for tibia. The infection rates were higher, reaching up to 2.9 %,3.2 % and 6.9 % for humerus, femur, and tibia fractures respectively if only nails which had registered follow-up were included in the study. The assumption for this was that patients who have not returned for follow-up do not have infection. Whether it an open or closed fracture possible risk factors for SSIs after orthopedic trauma surgery, include age, gender, surgical approach, antibiotics use, operating techniques and soft tissue condition. In IMNs in which Prophylactic antibiotics were used reduce the risk of infection by around 30%. Operations for non-union had a doubled (2.31times) risk of infection for reasons of larger exposure, longer operating time, and higher expected bleeding. The risk of infection was 33% higher in women than men. Infection risk is also associated with the level of income of a country which is 2 times higher in low-income countries as compared to middle income countries due to lack of infrastructure, high prevalence of malnutrition and immune suppression. In this study, 17.0 % of fractures are open fractures. Open fractures were 1.23 times (AOR=1.23,95%CI:0.97–1.55) more likely to develop infection than closed fractures. An open fracture of any grade gave 3.16 times increased adjusted risk of infection (OR 3.16, 95 % CI 2.62–3.80; $p<0.001$). This risk increases as Gustilo grade increases accounting 1.9 times for type 1 fracture to 7.6 times increased risk of infection for Gustilo type 3c fracture. No significant difference in the risk of infection was found between retro-grade and ante-grade approach of the nailing of the femur, between humerus and femur fractures. However, tibia fractures had two times increased risk of infection when compared to ante grade nailing of the femur. Method of reaming, open reduction, age, gender and number of distal screws did not have a significant adjusted risk of postoperative infection. The overall follow up rate was 23. 1%. The male to female ratio was 4:1 with a mean age of 34.7 years (women, 40.6 years and men, 33.3 years).Infection rate was higher in patients ≥30 years(55%) as compared to those under 30 years of age [2].

In another observational study conducted on Clinical outcome of patients with isolated tibial shaft fractures treated with S.I.G.N interlocking nails in terms of surgical site infection and radiological bone healing on follow up 12 weeks from January 2010 to October 2014 at Allied Hospital Faisalabad, Pakistan based on chart reviews and SOSD; The overall risk of surgical site infection for closed and Gustilo type 1 open fractures was comparable accounting 3.75% .80 patients were included in the study and the male to female ratio of fractures was 2.3:1 and the mean age was 35.86±10.42 years. Majority of the fractures occurred in ages between 21-30 years (35%) followed by ages 31-40 years(30%) [16].

In a prospective cohort study done using SOSD on risk factors for infection after intramedullary (SIGN) nailing of open tibial shaft fractures in low- and middle-income countries worldwide in multiple hospitals from 2000 to 2013 G.C; the overall rate of infection was 11.9%. More severe soft-tissue injury, delayed nailing, delayed wound closure, and distal fracture location were identified as risk factors for infection. Increasing Gustilo and Anderson fracture type was associated with an increased risk of infection (OR 1.466, 95% CI (1.15–1.87), P=0.002] which were of Gustilo type 1: 5.1%, type II:12.6%, type IIIa: 12.5%, type IIIc: 29.1%, and type IIIc: 16.7% (P=0.001 between groups). Patients who developed infection had a longer mean time from injury to definitive surgery accounting 4.7 days and 3.9 days in patients with infection and those without infection respectively (p=0.03). The distal fracture location had a higher infection rate than mid shaft fractures (13.3% vs. 8.2%, P= 0.03) but not proximal fractures (13.3% vs. 12.1%, P=0.88). Similarly, controlling for age and sex, increased time from injury to surgery was associated with a significantly higher infection rate [odds ratio (OR) 1.06,95% CI (1.001–1.13), P= 0.048]. There is no significant association in infection rates with time from injury to initial debridement (p=0.27), time from injury to initial antibiotic administration (p=0.42-0.78), total duration of antibiotics (0.64), age (p=0.11) and sex (p=0.94) [17].

In a prospective study on Incidence and Risk Factors Associated with Infection after Intramedullary Nailing of Femoral and Tibial Diaphyseal Fractures study done in 2018 in a 12 month follow up; the overall Incidence of SSI associated with IN for femoral and tibial diaphyseal fractures was 11.8%. The mean±SD interval between fracture and IMN was 7.8± (6.9) days. The mean ±SD duration of the surgical procedure was 187.4± (74.7) minutes. However; either of these factors have no association with occurrence of infection. All patients included in the study received antimicrobial agents at the time of IMN. In this study Previous external fixation and the need for soft-tissue reconstruction are associated with the occurrence of infection. There was a 2.53 times higher risk of infection among patients who had been previously subjected to external fixation (AOR=2.53,95%CI0.98 – 6.56). Regarding the fracture patterns segmental (AOR=8.75,95%CI:1.11 – 69.3) multifragmentary/irregular (AOR=4.84,95CI:0.60 – 38.73) were associated with occurrence of infection [3].

In a validation study of low infection rates of the surgical implant generation network (SIGN) done in 2011 using the SOSD after 34,361 intramedullary nail operations in 55 low- and middle-income countries excluding humerus and hip fractures; Overall follow-up rate was 18.1% (95%

CI: 17.7–18.5). The overall infection rate was 0.7% (CI: 0.6–0.8) and 1.2% (CI: 1.0–1.4) for femur and tibia fractures respectively. Infection rates were 3.5% (CI: 3.0–4.1) and 7.3% (CI: 6.2–8.4) for femur and tibia fractures respectively when only nails with a registered follow-up visit were included. Infection rates increase with increasing follow-up rates up to a level of 5%, but not above 5%. In this study, in Ethiopia 347 femur and 120 tibia nail operations were included with a follow up rate of 41% and 37% for femur and tibia nail patients respectively. The overall infection rate was 1.7% (CI: 0.4–3.1) for femur and 2.9% (CI: 0.0–0.9) for tibia fractures[18].

In Ethiopia studies specifically done on surgical site infections are lacking, but a prospective descriptive study done by E. Ahmed on outcome of S.I.G.N nail initiative in treatment of long bone fractures on 180 fractures of femur and/or tibia which are fixed using sign intramedullary nail and screw, in Addis Ababa, Ethiopia showed that the overall rate infection of tibial and femoral fractures is 2.8% which usually varies depending on the degree of injury. It accounts 13.6% for open fracture and 1.3% for closed fractures. Where as in developed world the average rate of infection is 10% and 1-3% for open and closed fractures respectively. In Ethiopia, the infection rate is relatively higher in open fractures due to delayed wound care, debridement and wound closure as compared to the developed world. The most common cause of injury was RTA with male to female ratio of 3:1. It predominantly affects young males accounting around 75% with an average age of injury being 34 years. The most common fracture patterns were 37% simple, 40% wedge and 23% complex. 5.2% were positive for HIV among 70% tested. Unstable fracture patterns (wedge and complex) were highly likely to develop post-operative complication [1].

Conceptual frame work

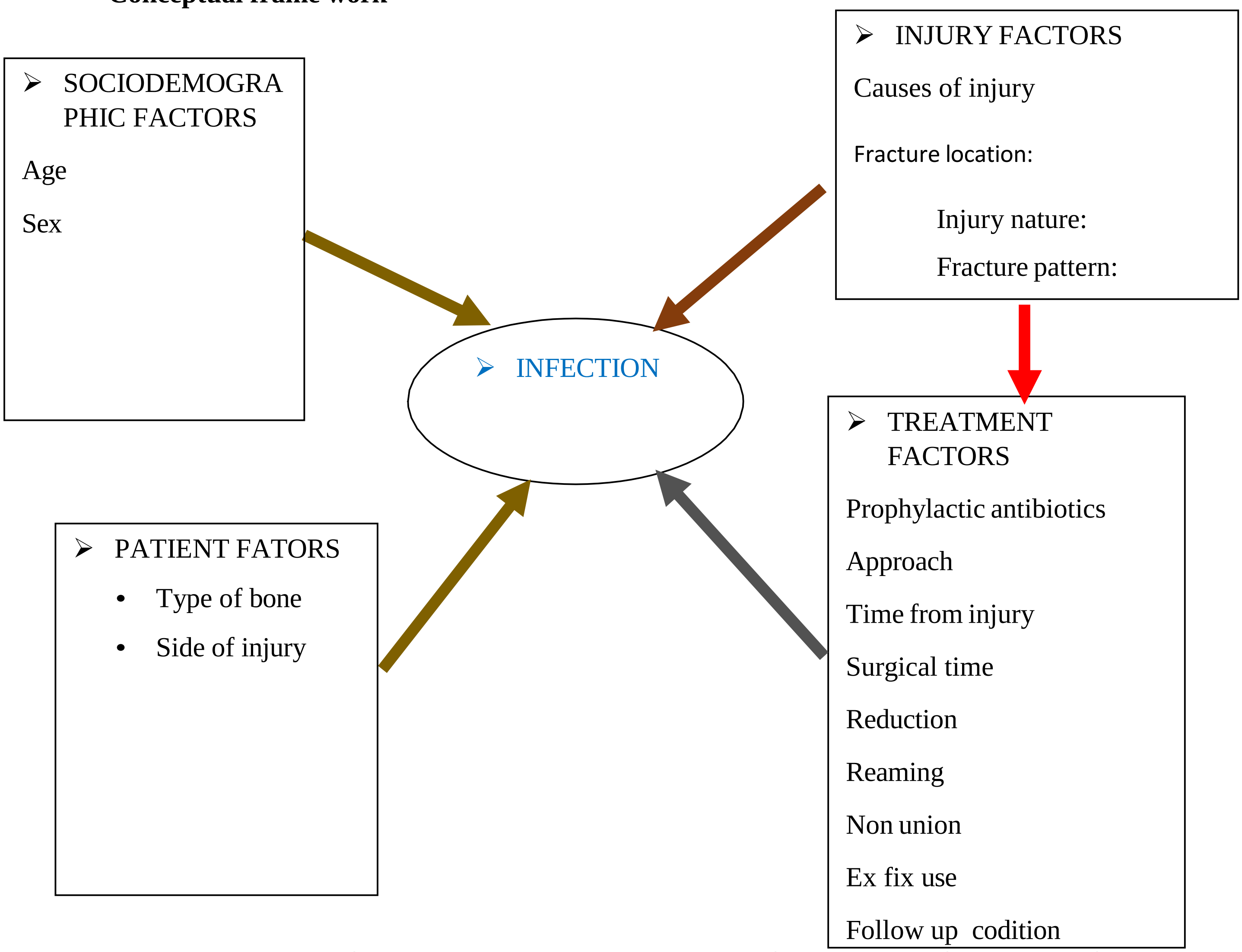

Figure 1: Conceptual framework to estimate the incidence of SSI and identify associated factors after SIGN nail in TGSH, Bahrdar, Ethiopia [2],[1, 3], [17].

3. Objective:

3.1 General objective:

To estimate the incidence and factors associated with surgical site infection after intramedullary nailing of long bone fractures

3.2 Specific objective:

To estimate the incidence of infection after intramedullary nailing of long bone fractures

To identify factors associated with surgical site infection after intramedullary nailing of long bone fractures.

4. Methods and materials

4.1 Study area

This study was conducted in the department of orthopedics & trauma surgery in TGSH.TGSH is one of the biggest specialized university hospitals in Amhara region and in the country at large. It was established in 2011 E.C /2018 G.C which landed in an area of 10000sq. M to primarily give service at a low cost or even free of charge to those that are unable to afford care elsewhere and at the time it was constructed to serve 2000 people per day. The hospital has more than 500 beds in all its wards and over 67 beds in orthopedics and trauma surgery ward; total of 8 orthopedic surgeons (2 of them are on fellowship) and 35 residents specializing in orthopedic surgery. Operations are done 4 days in a week as elective case and daily for emergency cases. The department have its own major operation room with two operating tables. The hospital has a separate SIGN follow up clinic which is used to follow SIGN patients, report the surgeries and squat and smile photos online. The study was be conducted on SIGN patients in SIGN clinics by reviewing charts from the hospital record rooms and online database records from SOSD.

4.2 Study Design

A retrospective, cross-sectional study design was used to conduct the study on patients admitted to TGSH

4.3 Study period

The study was conducted on cases from January 1, 2018 to September 30, 2020.

4.4 Source population

All Patients admitted with a diagnosis of long bone fractures in the orthopedic surgery department at TGSH.

4.5 Study population

All Patients operated with SIGN nail in orthopedic surgery at TGSH fulfilling the inclusion criteria listed.

4.6 Inclusion criteria

- Patients with long bone fractures admitted to the orthopedic surgery department or presented with nonunion and operated with SIGN implant.
- Patients whose operations are fully documented on the chart or obtained from electronic data from SIGN online surgical database.

- Whose follow up status is clearly known (clearly documented on follow up database or chart).
- Both standard nails and/or Fin nails will be included as SIGN nail cases.
- Fractures in bilateral and floating knee cases were taken as separate cases.

4.7 Exclusion criteria

- Patients who developed surgical site infection after one year.
- Patients who are operated with intramedullary nailing other than SIGN nail.
- Patients with SIGN nails done in other hospitals but are in follow-up in TGSH.
- SIGN nails used other than long bone fracture fixation operations; For instance, joint fusion.
- SIGN nails used for the indication of deformity or shortening in a completely healed fracture

4.8 Sample size

There is no specific data on the incidence and associated factors of SSI after SIGN nailing in Ethiopia. Therefor, 50% prevalence of SSI among patients with SIGN nailing is taken to obtain a maximum sample size.

The minimum number of samples required for this study was determined by using single population proportion formula.

$$n = \frac{(z_{\alpha/2})^2 \cdot pq}{d^2}$$, p=q=0.5

Where: n= minimum sample size required for the study

Z= standard normal distribution (Z=1.96), CI of 95% = 0.05

P= prevalence of surgical site infection is unknown; Hence; p=50 % (0.5) will be used

d=Absolute precision or tolerable margin of error= 5 % (0.05)

Sample size : $k = \frac{Z^2 p(1-p)}{d^2} = \frac{1.96^2 x 0.5(0.5)}{(0.05)2} = 384$

The total source population during the study period is 401 (N < 10,000). The correction formula depicted below is applied.

nf= $k/(1 + \frac{n}{N})$ = 384/ (1+384/401) = 196.16~197

Although the final sample size is 197, all the source populations (401) were included in the study.

4.9 Sampling technique

All patients admitted to TGSH with a diagnosis of long bone fractures and operated with SIGN implant from Jan 1/2018 to September 30/ 2020G.C fulfilling the inclusion criteria were taken by reviewing the SIGN database and the charts from hospital records.

4.10 Data collection

Data was collected from SIGN surgical data base and charts from hospital records from October 1 to December 10 by two data collectors (GPs) after being trained a head of data collection in the study period. Data collection format containing variables was prepared.

4.11 Study variables

4.11.1 Dependent variables:

- ✓ surgical site infection after IMN

4.11.2 Independent variables

- Age
- Sex
- cause of injury
- side of limb injured
- Type of long bone fracture
- Location of fracture
- pattern of fracture
- Nature of fracture
- Severity of injury
- Prophylactic antibiotics before surgery
- Surgical approach
- Method of reduction
- Method of reaming
- Duration of surgery(minutes)
- Time from injury to definitive surgery (days)
- Previous nonunion
- Previous external fixator

- Followed up status

4.12 Operational Definitions

- Surgical site infection: pussy discharge (erythematous change) at/around the incision site recognized by the patient or seen by the surgeon at follow up after operation.
- Two or more debridements after insertion of the implant with documented wound infection by the surgeon on wounds around the implant is considered infected
- Followed up: A patient at least having one follow up is considered to have a follow up
- Each bone is considered as separate case in bilateral and floating knee cases.

4.13 Data quality, processing and analysis

Data was coded, entered, cleaned and further analysis was done using Statistical package for social science (SPSS) windows version 23. Data was entered by giving a great care to keep the quality. Frequency and cross tabulation were used to summarize descriptive statistics. Mean, median, standard deviation and percentage were used to display descriptive data. Logistic regression model was used to identify the predictors of surgical site infection. Variables having a p-value of ≤ 0.25 were considered on bivariable binary logistic regression analysis to select candidate variables for multivariable logistic regression. Variable with P-value <0.05 was considered as significant predictor variables in multivariable binary logistic regression analysis and the strength of the association between the independent and dependent variables was expressed using odds ratio (OR).

4.14 Ethical considerations

Ethical clearance was obtained from the IRB of BDU research ethics committee.

6. Results

From January 1, 2018 to September 30, 2020; 401 patients with long bone fractures with an indication for IMN were treated with SIGN implants by both standard nails and fin nails. Of these patients,16 could not be included in the study, resulting in the inclusion of 385 cases.

6.1. Patient related characteristics

The fractures were predominantly occurred in males. Most injuries affect the young age group and femur was most involved bone. (see table 1)

Table 1-distribution of potential patient related characteristics in SIGN patients, TGSH, Bahirdar, Amhara Region, Ethiopia, Jan.2018-Sept.2020 (N=385)

Variable	Category	Percent (%)/number)
Age(years)	Mean ± SD	33.41±14.25
	Median (min; max)	30(10;85)
	<30 years	55.6%(N=214)
	≥30 years	44.4%(N=171)
Gender	Male	79.7(N=307)
	Female	20.3(N=78)
Side of the limb	Left	51.9% (N=200)
	Right	48.1% (N=185)
Type of bone	Humerus	0.5% (N=2)
	Femur	64.9% (N=250)
	Tibia	34.6% (N=133)

6.2 Injury related characteristics

Majority of the fractures were closed. Most of these injuries were caused by road traffic accidents. (see table 3)

TABLE 2-distribution of potential injury related characteristics in SIGN patients, TGSH, Bahirdar, Amhara Region, Ethiopia, Jan.2018-Sept.2020 (N=385).

Variable	Category	Percent
Nature of fracture	Closed	61.0% (N=235)
	Open	39.0% (N=150)
Severity/grade of injury	Closed	61% (N=235)
	Open I	12.7% (N=49)
	Open II	10.1% (N=39)
	Open IIIA	16.1% (N=62)
Trauma mechanism	RTA	64.7% (N=248)
	Gunshot/blast	7.3% (N=28)
	Fall	11.4% (N=44)
	Crush by heavy object	0.3% (N=1)
	Blow/assault	0.5% (N=20)
	Other	15.8% (N=61)
Pattern of fracture	Simple	55.6% N=214
	Wedge	9.1% (N=35)
	Complex/multifragmentary	35.3 (N=136)
Location of fracture	Proximal	24.4% (N=94)
	Middle	46.5% (N=179)
	Distal	29.1% (N=112)

6.3. Treatment related characteristics

Average interval between fracture and IMN was 14.9 days. All of the patients received antimicrobial prophylaxis before surgery. (see table 4)

TABLE 3-distribution of treatment related characteristics in SIGN patients, TGSH, Bahirdar, Amhara Region, Ethiopia, Jan.2018-Sept.2020 (N=385).

Variable	Category	Percent
Interval between fracture and IMN (days)	Mean ± SD	14.91±17.64
	Median (min; max)	12(1;209)
Duration of the surgical procedure (minutes)	Mean ± SD	108.79± 32.13
	Median (min; max)	100(50;330)
Use of prophylactic antibiotics	Yes	100% (N=385)
Surgical approach	Antegrade femur	35.6% (N=35.3)
	Retrograde femur	29.4%(N=113)
	Antegrade humerus	0.5%(N=2)
	Tibia	34.8%(N=134)
Method of reduction	Open	97.1(N=374)
	Closed	2.9 (N=11)
Method reaming	Hand	100%(N=385)
Follow up status	Yes	99.7%(N=384)
	No	0.35%(N=1)
Previous non union	Yes	0.8% (N=3)
	No	99.2% (N=382)
Previous ex-fix	Yes	0.8%(N=3)
	No	99.2%(N=382)

6.4. occurrence of Surgical site infection after SIGN intramedullary nail

In a 33 month study a total of 20 cases of infection were observed in the study with an incidence of 5.2 %. It varies with the nature and severity of injury which is higher in open fractures than closed fractures. (see summery table 4)

TABLE 4-summary of associated factors and occurrence of infection in, TGSH, Bahirdar, Amhara Region, Ethiopia, Jan.2018-Sept.2020 (N=385).

Variable	Category	Infection	
		Number (from 20)	Percent (%)
Age	Less than 30 years	14	70
	Greater or equal to 30 years	6	30
Gender	Male	19	95
	Female	1	5
Cause of injury	RTA	11	55
	Bullet/gun shot	6	30
	Fall	1	5
	Other	2	10
Time from injury to surgery/date	Less than 15 days	18	90
	Greater or equal to 15 days	2	10
Surgical time	Less than 109 minutes	15	75
	Greater or equal to 109 minutes	5	25
Prophylactic antibiotics	Yes	20	100
Side of limb	Left	11	55
	Right	9	45
Surgical approach	Antegrade femur	7	35
	Retrograde femur	2	10
	Tibia	11	55
type of bone	Femur	9	45
	Tibia	11	55

Location of fracture	Proximal	6	20
	Middle	8	40
	Distal	6	20
Nature of fracture	Closed	4	20
	Open	16	80
Severity of injury	Closed	4	20
	Open grade I	2	10
	Open grade II	4	20
	Open grade IIIA	10	50
Pattern of fracture	Simple	6	30
	Wedge	2	10
	Complex/communited	12	60
Previous non union	No	20	100
Previous ex fix	Yes	1	5
	No	19	95
Method of reduction	Open	19	95
	Closed	1	5
Method of reaming	Hand	20	100
Follow up status	Yes	20	100

6.5. Association between Potential associated Factors and the Occurrence of Infection

Predictors for the occurrence infection were assessed using bi variable and multi variable logistic regression analysis to identify competent variables and assess presence or absence of association between the dependent and independent variables.

A total of 8 variables which have p value <0.25 were selected from results of bivariable binary logistic regression analysis and entered to multi variable binary logistic regression analysis model. (see table 5)

TABLE 5**:** Bi-variable binary Logistic Regression Analysis of factors related with surgical site infection at TGSH, Bahirdar, Amhara Region, Ethiopia, Jan.2018-Sept.2020 (N=385).

Variable	Category	Infection		p- value	COR (95%CI)
		Yes	No		
Nature of fracture	Closed	4	231		1
	Open	16	134	0.001	6.89 (2.26-21.05)
Pattern of fracture	Simple	6	208		1
	Complex	12	12	0.018	3.36 (1.23-9.16)
Time from injury to surgery	<15 days	18	216	0.026	6.21 (1.42-27.16)
	≥15 days	2	149		1
Previous use of external fixator	Yes	1	2	0.07	9.55 (0.89-110.08)
	No	19	363		1
Age	<30years	14	210	0.189	1.925 0.72-5.12
	≥30 years	6	165		1
Gender	Male	19	288	0.116	5.08 (0.699-38.57)
	Female	1	77		1
Cause of injury	RTA	11	237		1
	Fall	6	38	0.015	8.05 (1.51-42.9)
Injury severity	Closed	4	231		1
	OPEN I	2	47	0.307	2.457 (0.46-13.8)
	Open II	4	35	0.01	6.6 (1.58-27.6)
	OPEN IIIA	10	52	0.000	11.11 (3.35-36.78)

In a multiple binary logistic regression analysis model; nature of fracture, pattern of fracture, time from injury to surgery and previous use of external fixator were found to be significantly associated with occurrence of surgical site infection with a p-value <0.05. (Table 6)

The odds of surgical site infection in open fractures were 6.51 times (AOR=6.51,95%CI:2.05-20.65) higher than closed fractures.

The odds of surgical site infection in cases with complex fracture patterns were 3.7 times (AOR=3.70,95%CI:1.24-11.45) higher than in cases with simple fracture patterns.

The odds of surgical site infection in those cases whose surgical time from injury to surgery was under 15 days were 10.85 times (AOR=10.85,95%CI:2.26-52.01) higher than those cases whose surgeries were done 15 days or more.

The odds of surgical site infection in cases who were on external fixation prior to definitive surgery were 23.12 times (AOR=23.12,95%CI:1.09-493.93) higher than those cases whose fractures was not stabilized by ex-fix prior to surgery.

TABLE 6**:** Bi-variable and multi-variable binary Logistic Regression Analysis of factors related with surgical site infection at TGSH, Bahirdar, Amhara Region, Ethiopia, Jan.2018-Sept.2020 (N=385).

Variable	Category	Infection		p- value	COR (95%CI)	AOR (95%CI)
		Yes	No			
Nature of fracture	Closed	4	231		1	1
	Open	16	134	0.001	6.89 (2.26-21.05)	6.51 (2.05-20.65)
Pattern of fracture	Simple	6	208		1	1
	Complex	12	12	0.02	3.36 (1.23-9.16)	3.70 (1.24-11.45)
Time from injury to surgery	<15 days	18	216	0.003	6.21 (1.42-27.16)	10.85 (2.26-52.01)
	≥15 days	2	149		1	1
Previous use of external fixator	Yes	1	2	0.044	9.55 (0.89-110.08)	23.12 (1.09-493.93)
	No	19	363		1	1

7. Discussion

The present study showed that overall occurrence of infection after SIGN intramedullary nailing in TGSH is 5.2%. It was found to be higher in open fractures (10.7%) due to direct communication to the external environment and high energy nature of these injuries to both bone and soft tissues.

It was higher than a study done in Addis Ababa, Ethiopia by E. Ahmed in 2011 which showed that overall infection rate was 2.8%[1].Similarly it was higher than findings in a large multicenter study done by Sven Young and colleagues on 46 133 cases in LMICs in 2012,which showed that the overall infection rate was 1% [2].

In this study injuries with open fractures were 6.51 times more likely to develop infection than those with closed fractures. It is 10.7% in open fractures and 1.7% in closed fractures. It accounts 1.33%,2.67% and 10.67% for grade I, grade II and grade IIIA fractures respectively. The higher incidence of infection particularly in open fractures as compared to closed fractures in both studies is due to open contamination to the external environment, high energy nature of these injuries.

This is consistent with a study done in Addis Ababa, Ethiopia by E. Ahmed in 2011 which shows a higher incidence of infections in open fractures accounting 13.6% for open fracture and 1.3% for closed fractures. In a similar article it was stated as in the developed world the average rate of infection was 10% and 1-3% for open and closed fractures respectively[1].

In another large multicenter study done by Sven Young and colleagues which was published in 2012 study, 17.0 % of fractures were open. Open fractures were 1.23 times more likely to develop infection than closed fractures. An open fracture of any grade gave 3.16 times increased adjusted risk of infection [2].

As compared to Ethiopian study these findings showed that the overall and closed fracture infection rate was higher. However, it is lower in open fractures which can be justified by lower threshold to do SIGN surgery in high grade open fractures evidenced by zero SIGN nail done for Gustilo Anderson grade IIIB and IIIC fractures in TGSH.

However; as compared to the developed world infection rate is higher in all occasions due to contamination, delayed wound care, delayed debridement.

Complex fracture patterns were 3.7 times more likely to develop surgical site infection than those cases with simple fracture patterns. This finding was consistent with a prospective study done in 2018 by Oliveira and colleagues which shows that segmental and multifragmentary fracture patterns were associated with occurrence of infection [3].

It is also in line with a study done in Addis Ababa, Ethiopia in 2011 by E.Ahmed which showed that unstable fracture patterns (wedge and complex) were highly likely to develop post-operative complications like infection [1].

This finding can be justified by complex fracture patterns are associated with high degree of bone and soft tissue injury and long operative time.

In this study cases whose surgeries were done less than 15 days from injury to definitive surgery were 10.85 times more likely to develop surgical site infection than those cases whose surgeries were done 15 days or more.

However; significant association was not found between time from injury to definitive SIGN surgery and occurrence of infection in a prospective study done by Oliviera and colleagues in 2018[3].

This finding in our study can be justified by cases whose surgeries were delayed 15 days or more are either with clean, closed fractures or fractures with known infection status for treatment before inserting intramedullary nail. The high occurrence infections in earlier surgeries are due to early referral, earlier presentation of infection prone cases like open fractures and complex fractures as compared to simple and closed fracture. however, this highlights a need for further study to be done on infection and associated factors on immediate and delayed nailing.

Fractures who were on external fixation before surgery were 23.12 times more likely to develop surgical site infection than those cases whom external fixator was not used.

This finding was in line with a prospective study done by Oliveira and colleagues in 2018 which shows that there was a 2.53 times higher risk of infection among patients who had been previously subjected to external fixation [3].

These findings show the importance of the association of previous external fixation use and infection following SIGN intramedullary nails. This is because external fixator is used usually in high energy complex fractures which are prone to infection and the risk of pin site infections associated with it. This needs further study to analyze variables specific to external fixation use that may affect the occurrence of infection.

8. Strength and limitations

8.1. Strength

- The first study done in the study area (TGSH).

8.2. Limitations

- It is single center study.
- Being a retrospective study and cross-sectional study

9. Conclusions and recommendations

9.1. Conclusions

- The overall incidence of infection is higher than other low and middle income and developed countries. Time from injury to surgery, nature of fracture, pattern of fracture and previous use of external fixator were found to be significantly associated with occurrence of surgical site infection. Majority of long bone fractures were caused by road traffic accident in highly productive young age group.

9.2. Recommendations

- For Tibebe Ghion Specialized Hospital
    - More attention should be given to patients with long bone fractures on SIGN nails for complaints around the surgical wound. Open and complex fractures are at risk of infection and we need to have appropriate measures to prevent infection. It is good to be cautious and look predisposing factors for infection while doing nailing early and use ex fix.
- For Federal Ministry of Health and Regional Health Office
    - Measures to tackle road traffic accident should get enough emphasis as it is the leading cause of long bone fractures. Modern wound care technologies like VAC should be available in hospitals.
- For SIGN company
    - It is still possible for the SIGN IM nail to be used to fix long bone fractures in TGSH. There is huge burden of injuries and continuous supply of nails is necessary.
- For Researchers
    - It is a potential area to do further study prospectively so we recommend researcher to study prospectively specially to measure the association of outcome with details of associated factors.

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11. Annexes

Annex 1: Consent form

Title of the Research Project: Incidence and factors associated with surgical site infection after intramedullary nailing with surgical implant generation network (SIGN) of long bone fractures among SIGN patients in TibebeGhion Specialized Referral Hospital, Bahir Dar, Ethiopia

Name of Investigator: Misganaw Alemu (MD, orthopedic surgery Resident)

Name of the Organization: Bahir Dar university, College of Medicine and Health Sciences.

Name of the Sponsor: Bahir Dar university

Introduction: This information sheet was prepared for Bahir Dar university, college of medicine and health sciences administration to make concerned offices clear about the purpose of research, data collection procedures and get permission to conduct the research.

Purpose of the Research Project: To assess the incidence of infection in patients with long bone fractures who were treated using intramedullary nailing.

Procedure: In order to achieve the above objective, information which is necessary for the study was taken from medical records of the patients and SIGN online surgical database.

Risk and /or Discomfort: Since the study was conducted by taking appropriate information from medical chart and SIGN online surgical data base, it did not inflict any harm on the patients.

The name or any other identifying information was not recorded on the question table and all information taken from the chart was kept strictly confidential and in a safe place. The information extracted was kept secured. After the data was entered in to the computer it was locked by password. The information retrieved was used for the study purpose.

TABLE 7:data collection format used to collect data from case records in SIGN patients, TGSH, Bahirdar, Amhara Region, Ethiopia, Jan.2018-Sept.2020 (N=385).

Cases	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Case ID				
Age				
Sex				
Type of bone 1-humerus 2-femur 3-tibia				
Pattern of fracture 1.simple 2.wedge/butterfly 3.complex/comminuted/segmental				
Fracture side 1. Left 2. Right				
Mechanism of injury: 1-RTA 2- bullet/blast 3-fall down ,4-crush by heavy object 5-blow/assault 6-other (pathological)				
Fracture location 1-proximal,2-middle, 3-distal				
Nature of injury 1-closed,2-open				
Severity of injury Gustilo-Anderson grade				

Closed, I, II, III, IIIA, IIIB, IIIC				
Prophylactic antibiotics before surgery 1.yes,2.no				
Previous non union 1.yes,2.no				
Previous Ex fix used 1.yes 2.no				
Surgical approach 1.antegrade femur 2.retrograde femur 3.antegrade humerus 4.tibia				
Fracture reduction – 1. open 2. Closed				
Reaming 1.hand 2. power 3.non reamed				
Duration of surgery (in minutes)				
Date of surgery after injury (in days)				
Follow up 1.yes 2.no				
SSI (yes, no)				

12. Declaration

I, the under signed, declared that this is my original work has never been presented in this or any other university, and that all the resources and materials used for the research, have been fully acknowledged.

Principal investigator (PI)

Name: Misganaw Alemu (MD, orthopedic surgery Resident)

Signature____

Date____

Advisors

1. Name: Gedefaw Abeje (PHD, Reproductive health sciences)

   Signature____

   Date____

2. Name: Bahru Atinafu (MD, consultant orthopedic surgeon)

   Signature____

   Date____