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ORIGINAL SCIENTIFIC REPORT

The Cost of Intramedullary Nailing Versus Skeletal Traction for Treatment of Femoral Shaft Fractures in Malawi: A Prospective Economic Analysis

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Abstract

Background In many low- and middle-income countries, non-surgical management of femoral shaft fractures using skeletal traction is common because intramedullary (IM) nailing is perceived to be expensive. This study assessed the cost of IM nailing and skeletal traction for treatment of femoral shaft fractures in Malawi.

Methods We used micro-costing methods to quantify the costs associated with IM nailing and skeletal traction. Adult patients who sustained an isolated closed femur shaft fracture and managed at Queen Elizabeth Central Hospital in Malawi were followed from admission to discharge. Resource utilization and time data were collected through direct observation. Costs were quantified for procedures and ward personnel, medications, investigations, surgical implants, disposable supplies, procedures instruments and overhead.

Results We followed 38 nailing and 27 traction patients admitted between April 2016 and November 2017. Nailing patient's average length of stay (LOS) was 36.35 days (SD 21.19), compared to 61 (SD 18.16) for traction ($p = 0.0003$). The total cost per patient was $596.97 ($168.81) for nailing and $678.02 (SD $144.25) for traction ($p = 0.02$). Major cost drivers were ward personnel and overhead; both are directly proportional to LOS. Converting patients from traction to nailing is cost-saving up to day 23 post-admission.

Conclusion Savings from IM nailing as compared with skeletal traction were achieved by shortened LOS. Although this study did not assess the effectiveness of either intervention, the literature suggests that traction carries a higher rate of complications than nailing. Investment in IM nailing capacity may yield substantial net savings to health systems, as well as improved clinical outcomes.

Introduction

Eleven percent of the global burden of disease has been attributed to surgical conditions [1], with a disproportionate burden on low- and middle-income countries (LMICs) where the largest portion of the world's population resides and the lowest percentage of surgical output occurs [2]. As a result of increased violence, conflicts and access to motorized transportation, musculoskeletal injuries represent a great proportion of the surgical burden. Musculoskeletal injuries in LMICs have an estimated incidence between 1000 and 2600 per 100,000 population [2]. Fractures of the femoral shaft have a very high incidence in

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LMICs, representing 17% of all musculoskeletal injuries, [3, 4] and if left untreated, they can result in long-term disability [5, 6].

Intramedullary (IM) nailing is the gold standard treatment for femoral shaft fractures. As compared to skeletal traction, IM nailing is better in terms of fracture union and return to function. In LMICs, the infection rate after IM nailing ranges between 0.7 and 5% [7, 8]. On the other hand, studies assessing skeletal traction reported 4–9% malunion rates, 6–10% non-union rates, and 11–43% pin-tract infection rates [9–12]. Many LMICs still use skeletal traction for 6 weeks or more as the primary method of treatment. The reasons for continued use of non-operative treatment include lack of expertise, implants, equipment, proper operating rooms, as well as the perception that intramedullary nailing is expensive [13–15]. To address lack of access to implants, SIGN Fracture Care International, a US-based NGO, started to manufacture and donate intramedullary nails beginning in 1999. The SIGN nail is designed to be used in resource-limited settings without the need of fluoroscopy, or other power instruments [16]. However, despite these efforts intramedullary nailing as a method of treatment is still not universally available in LMICs, especially in public hospitals.

Economic evaluation of health interventions is paramount in informing policy decisions regarding resource allocation, especially in resource-limited settings. The available data on the costs of surgery for femoral shaft fractures are sparse and methodologically flawed, particularly with respect to how the cost data were collected [17–19]. Prior studies have used retrospective data relying primarily on hospital fees, which may not accurately represent the true cost of each treatment strategy. In this investigation, we aimed to compare the cost of skeletal traction to IM nailing for femoral shaft fractures in Malawi using robust micro-costing methods and prospectively collected data, which has not been done previously.

Materials and methods

Study design and setting

This was a prospective observational economic analysis study at Queen Elizabeth Central Hospital (QECH), Blantyre, Malawi. QECH is a tertiary government hospital, and it is the main teaching hospital for the University of Malawi College of Medicine. It is the referral hospital for all districts in the southern region of the country. In 2016, there were 78,353 hospital admissions, of which 827 were orthopedics admissions.

Patients

All adult patients (18 years or older) who sustained an isolated closed femur shaft fracture and managed at QECH between April 2016 and November 2017 were followed from admission to discharge. Patients with pathological fractures, poly-trauma or additional injury requiring admission on its own merit were excluded.

Procedures

IM nailing was performed in the operating theater without the use of fluoroscopy and under spinal anesthesia. With the patient positioned supine, an incision was made at the level of the fracture and the femoral canal was reamed manually through the fracture site. Following the manufacturer's instructions [20], a nail diameter 2 mm smaller than the largest reamer was selected. Two approaches for nail insertion were commonly used: antegrade, where the nail was inserted just medial to the tip of the greater trochanter, or retrograde, where a start site through the knee was used. The fracture was reduced manually through the open incision, and the nail was passed across the fracture site. Typically, four interlocking screws were used to lock the nail, two proximally and two distally using a target arm.

Skeletal traction was performed in the general ward under local anesthesia. With patient supine, the traction pin was inserted 2 cm below the tibial tubercle. A stirrup made of plaster of Paris (POP) was fixed to the pin. Traction force was applied through weights fixed to the stirrup by a crepe bandage and hung from the end of the patient's bed.

Costing framework

We used micro-costing methods to quantify the direct and indirect hospital costs associated with IM nailing and skeletal traction. Resource utilization and time data were collected through direct observation using time and motion (TM) analysis and patients' charts. Time and motion is a quantitative data collection method in which an observer captures detailed data on the duration and movements required to complete a specific task [21]. Prices were obtained from hospital records, Malawi Central Medical Store Trust (CMST) catalog [22] and the implant supplier [16]. Direct costs were quantified for procedures and ward personnel, medications, laboratory and radiology investigations, surgical implants, procedure instruments and disposable supplies. Indirect overhead costs included food, building maintenance, renovation, cleaning and sanitation, beddings, stationery, uniforms and protective gear, staff training and maintenance.

Direct costs

Procedure personnel and supplies

Two research assistants were trained to collect the data by direct observation using Excel (Microsoft, Seattle, WA) spreadsheets. For IM nailing, we identified 18 unique steps for the nailing procedure, starting with transport from the ward to theater and including all points of care until transporting back to the ward. Seven steps for the traction procedure were identified, starting from the administration of local anesthesia to bed cleaning immediately following the procedure. The time spent in each step, resources used and the personnel involved were recorded. The data were used to calculate total procedure personnel time by health worker cadre. We obtained a wage multiplier from QECH human resources and used Eq. 1 ("Appendix A") to calculate the personnel cost per procedure. Costs for all personnel were summed to arrive at the total procedure personnel cost. Supplies included intraoperative medications, disposables, intravenous fluids, blood products, and others. The average cost of supplies for IM nailing and skeletal traction was calculated by multiplying prices by utilization.

Ward personnel

We observed and counted the typical ward personnel present in the day shift (7.30 am–4.30 pm) and night shift (4.30 pm–7.30 am) and obtained the hourly wages by cadre. The average number of patients per day was calculated by dividing the average monthly inpatient days by 30. Equation 2 ("Appendix A") was then used to calculate the personnel cost per patient per day.

Medications and investigations

Type and quantity of medications and investigations were recorded from the patient chart. The labor and resource costs of radiographs and laboratory investigations were obtained from the radiology department and the hospital laboratory. Average cost per patient was then calculated for each intervention.

IM nailing implants

Prices were obtained directly from the supplier. Although SIGN implants are typically donated at no cost to the recipient hospital, we used the manufacturing cost for all calculations, to estimate the economic cost from a health-system's perspective. This method was used previously [23].

Procedures instruments

The cost of surgical instruments was provided by the manufacturer. The life expectancy of surgical instruments was assumed to be 10 years [24, 25]. Equation 3 ("Appendix A") was used to calculate the depreciated equipment cost.

Indirect (overhead) costs

Overhead costs of the orthopedics department were obtained from the hospital accountant and procurement office. We calculated the overhead cost per patient per day using Eq. 4 ("Appendix A"). We multiplied the cost per patient per day by the average length of stay (LOS) to arrive at the cost for each intervention.

All costs were converted from Malawian kwacha to 2017 US dollars at an average exchange rate of MK713.72 to $1.00 [26].

Statistical analysis

Data analysis was done using Stata software version 14 [27]. Means, standard deviations, medians and interquartile ranges (IQR) were calculated for continuous variables. Time from injury to current admission was categorized into <1 week, 1–2 weeks, 2–4 weeks and >4 weeks. Frequency distributions were presented for all categorical variables. Comparisons between IM nailing and skeletal traction patients were done using a two-sample t test for numeric variables and Chi-squared or Fisher's exact testing for categorical variables. A linear regression was performed for age, gender, fracture site (left and right), fracture location (proximal, mid-shaft and distal) and time from injury to admission as predictors of length of hospital stay. For IM nailing patients, Wilcoxon signed-rank test was used to compare the length of stay for fresh fractures (<1 week) and old fractures (>6 weeks). p values <0.05 were considered statistically significant. A one-way sensitivity analysis was done to show the effect of reducing length of stay on the total cost of nailing.

Results

Of the sixty-five patients included in the final analysis, 38 were managed by IM nailing and 27 by skeletal traction (Table 1). The average age was 38 (SD 15) for IM nailing and 41 (SD 17) for traction patients ($p = 0.44$). For both groups, the majority of fractures were due to road traffic accidents (78% and 67% for nailing and traction, respectively), followed by falls (16% and 22%) and other causes (5% and 11%). Males represented 81.6% of the nailing

Table 1 Characteristics of femur fracture patients treated by IM nailing or skeletal traction at QECH, Malawi 2016-2017

	IM nailing	Skeletal traction	*p* value
Number of observations	38	27	
Age			0.44
Range	19–94	22–86	
Mean (SD)	38.34 (15.06)	41.44 (17.26)	
Median (IQR)	34.5 (21–62)	40 (23–70)	
Gender, n (%)			0.99
Male	31 (81.6%)	22 (81.5%)	
Female	7 (18.4%)	5 (18.5%	
Cause of injury, n (%)			0.53
RTA	29 (78.4%)	18 (66.7%)	
Fall	7 (16.2%)	6 (22.2%)	
Others	2 (5.4%)	3 (11.1%)	
Site, n (%)			0.58
Right	26 (68.4%)	21 (77.8%)	
Left	12 (31.6)	6 (22.2%)	
Location, n (%)			0.76
Proximal	13 (34.3%)	8 (29.6%)	
Mid-shaft	18 (47.4%)	12 (44.4%)	
Distal	7 (18.4%)	7 (25.9%)	
Time from injury to admission			0.006
Mean (SD)	26.23 (43.35)	2.22 (3.37)	
Median (IQR)	1.5 (0–32)	0 (0–3)	
<1 week, *n* (%)	25 (65.79%)	24 (88.89%)	
1–2 weeks, *n* (%)	0 (0.0%)	3 (11.1%)	
2–4 weeks, *n* (%)	1 (2.63%)		
>4 weeks, *n* (%)	12 (31.58%)		

SD standard deviation, *IQR* interquartile range

group and 81.5% of the traction group (Table 1). The median time from injury to admission was 1.5 days (IQR 0–32) for nailing patients and 0 days (IQR 0–3) for traction patients (Table 1). The difference in time from injury to admission IQR is explained by a group of IM nailing patients who were transferred from district hospitals after an attempted skeletal traction.

Overall resource use and costs

IM nailing average total LOS was 36 days (SD 21.2) compared to 61 days (SD 18.2) for traction ($p = 0.0003$). The pre-procedure LOS was 17.86 (SD 18.05) for nailing and 10.59 (SD 15.07) for traction (Table 2). Age ($p = 0.23$), gender ($p = 0.30$), fracture location ($p = 0.60$) and time from injury to admission ($p = 0.11$) were not found to be independent predictors of LOS.

The total cost for IM nailing was $597 (SD $169) compared to $678 (SD $144) for traction ($p = 0.02$) (Fig. 1). A one-way sensitivity analysis showed total costs to be directly proportional to LOS at a rate of ~$10.44 per day. Converting a patient from traction to IM nailing was cost-saving up to 23 days after admission (Fig. 2). A subgroup analysis was done for a group of 19 IM nailing patients who were transferred from district hospitals after an attempted non-surgical management. This group has an average time from injury to admission of 49 days (SD 52) compared to 3 days (SD 8) for patients who were directly admitted to QECH ($p = 0.0005$). Directly admitted patients had an average LOS of 32 (SD 18) as compared to 41 days (SD 24) for transferred patients ($p = 0.20$). If only patients who presented directly to QECH for IM nailing were considered, then the total IM nailing cost would be $551.5 (SD $143.7), compared to $649.7 (SD $191) for the transferred group ($p = 0.082$).

Table 2 Treatment data of femur shaft fracture patients treated by IM nailing or skeletal traction at QECH, Malawi, 2016–2017

	IM nailing	Skeletal traction	*p* value
Number of observations	38	27	
Length of stay in days, mean (SD)			
Admission to procedure	17.86 (18.05)	10.59 (15.07)	0.09
Procedure to discharge	17.38 (14.72)	45 (25.77)	<0.0001
Total length of hospital stay	36.35 (21.19)	61 (18.16)	0.0003
IM nailing approach (n = 37)			
Retrograde (%)	11(30%)	N/A	
Antegrade (%)	26 (70%)	N/A	

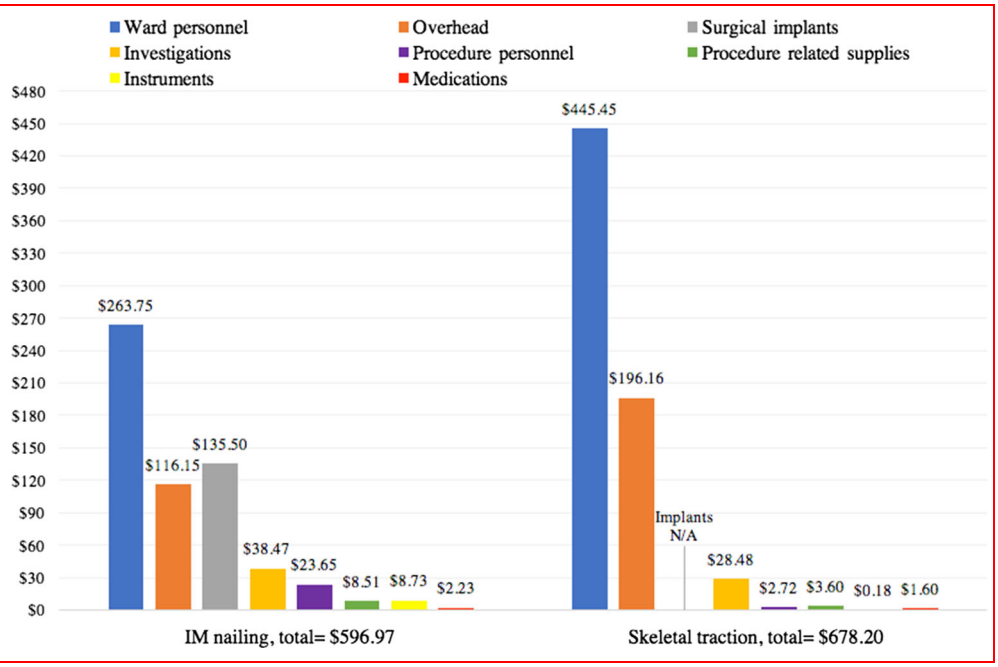

Fig. 1 Direct and indirect costs of IM nailing and skeletal traction for treatment of femur shaft fractures at QECH, Malawi 2016–2017

Direct costs

The average direct cost was nearly identical at $480.83 (SD 70.18) for IM nailing and $481.85 (SD $144.26) for skeletal traction (Fig. 1). The typical personnel involved in IM nailing were surgeons, registrars, anesthetic clinical officers (ACOs), scrub nurses, theater assistants, recovery nurses, porters and ward nurses. The total procedure personnel cost was $23.65 (SD $2.83). ACOs had the longest mean personnel time at 1.84 h per procedure, and surgeons had the largest cost at $12.03 (SD $2.47) per procedure (Table 3). For traction, the typical personnel were orthopedic clinical officers (OCOs). Two OCOs were required to complete the procedure, one as the main personnel and the other as the assistant. The total traction procedure personnel cost was $2.72 (SD $0.65) (Table 3). Procedure supplies were 2% and 1% of the total cost for nailing and traction, respectively.

The typical ward personnel during the day shift were one surgeon, three registrars, two medical interns, two registered nurses (RNs) and six nurses and midwife technicians (NMTs). During the night shift, there were two registrars, one medical intern and four NMTs. The ward personnel cost was $4.89 per day and $2.35 per night. The total ward personnel cost per IM nailing patient was $264 (SD $154), and it was $436 (SD $134) per traction patient.

The average medication cost per patient was $2.23 (SD $1.61) for nailing and $1.60 (SD 1.87) for traction. The average cost of investigations per patient was $38.50 (SD $17) and $28.50 (SD $9) for nailing and traction, respectively. Instrument cost was $8.70 for nailing and $0.20 for traction. The implant cost per patient was $135.45 or 25% of the IM nailing total cost. The threshold implant cost

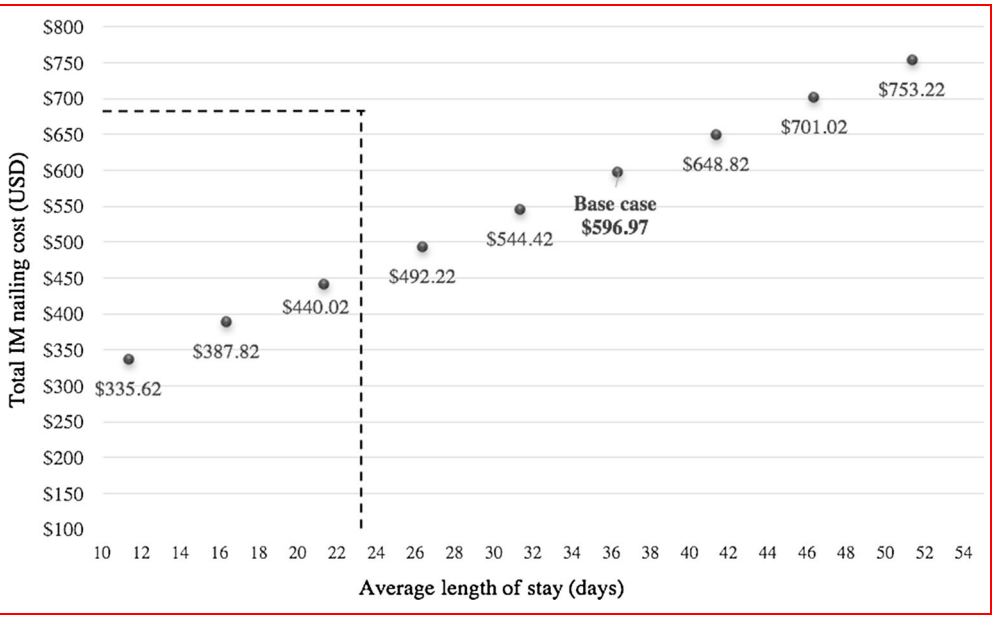

Fig. 2 One-way sensitivity analysis of IM nailing total cost by average lengths of stay. At a base-case IM nailing LOS of 36 days, transferring a traction patient to IM nailing at up to 23 days from the date of admission is cost-saving (dotted line = $671.3) as compared to continued management by traction

Table 3 Typical IM nailing and skeletal traction procedure personnel time and cost. QECH, Malawi 2016–2017

Personnel	Time in hours, mean (SD)	Mean hourly wage	Cost per procedure (SD)
IM nailing			
Surgeon	1.79 (0.37)	$6.73	$12.03 ($2.47)
Registrar	1.75 (0.35)	$2.9	$5.07 ($1.01)
Anesthetic clinical officer (ACO)	1.84 (0.33)	$2.17	$4.05 ($0.72)
Scrub nurse	1.64 (0.34)	$1.01	$1.66 ($0.35)
Theater assistant	0.54 (0.75)	$0.50	$0.27 (0.37)
Recovery nurse	0.30 (0.11)	$1.01	$0.30 ($0.11)
Ward nurse	0.18 (0.14)	$1.01	$0.18 ($0.14)
Porter	0.26 (0.17)	$0.50	$0.13 ($0.09)
Total cost per procedure			$23.65 ($2.83)
Skeletal traction			
Lead orthopedic clinical officer	0.65 (0.20)	$2.17	$1.41 ($0.43)
Assistant orthopedic clinical officer	0.60 (0.23)	$2.17	$1.31 ($0.49)
Total cost per procedure			$2.72 ($0.65)

after which IM nailing becomes more costly than traction is $216.50 (Fig. 3).

Indirect costs

The overhead cost per patient per day was $3.19. The overhead cost for IM nailing patients was $116 (SD $68) compared to $196 (SD $58) for skeletal traction (Fig. 1). Combined with ward personnel cost, they represented 60% and 93% of the total costs for IM nailing and traction, respectively.

Discussion

We conducted a micro-costing study to estimate the costs associated with surgical and non-surgical treatment for femoral shaft fractures in Malawi. We found that IM nailing was associated with 12% lower cost than skeletal traction. This was despite the fact that the average time from admission to surgery was 18 days, and many of the IM nailing cases were delayed in presentation due to having received a trial of skeletal traction at a district hospital prior to transfer.

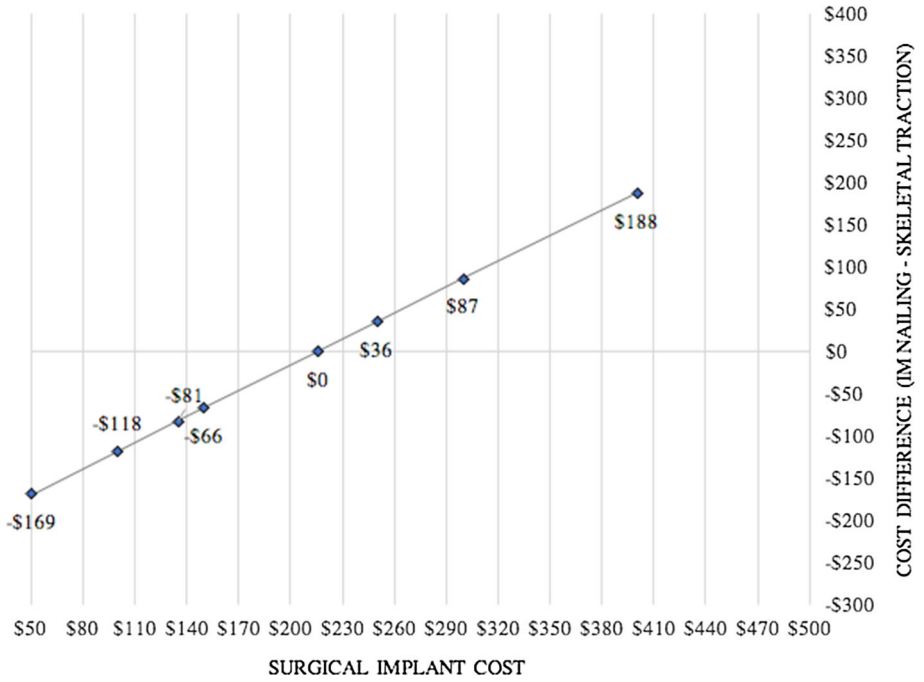

Fig. 3 One-way sensitivity analysis on the impact of IM nailing implant cost on the total cost. The threshold implant cost at which the cost of IM nailing equals that of traction in QECH is $216 USD

The major cost driver was length of stay, which was—not surprisingly—significantly longer for skeletal traction. At 61 days, traction length of hospital stay reported in this study is similar to other studies conducted in LMICs (52–66 days) [12, 17–19]. However, the duration of hospital stay for IM nailing (36 days) was longer than previous reports [28–30] primarily due to a nearly 3 weeks delay from admission to surgery. These long delays were related to the limited availability of implants, surgical personnel and operating room space. QECH, a third-level tertiary referral center for Malawi had only one theater available for orthopedic surgery at the time of the study. Despite these long delays, IM nailing remained less costly than skeletal traction, a finding that would be strengthened if access to the operating theater were improved. Increasing the limited access to operating theaters is a complex multifactorial challenge. Nevertheless, adding operating theaters and improving surgical capacity would result in substantial cost savings, creating fiscal space for other needed investments in health [31].

Overhead and ward personnel represented 60% of the IM nailing cost and 93% of the traction cost. Gosselin et al. conducted a study in Cambodia [18] reporting similar findings; they estimated the per diem (nursing care, food, laundry and hospital cleaning) to be 66% of the nailing cost and 88% of the traction cost. Their reported per diem was $15.5 per day, which was 33% higher than our estimate of $10.45 per day. This difference is expected, as Cambodia has higher public facility costs than Malawi [32, 33], and it explains the higher reported cost estimates in Cambodia ($820 and $941 for nailing and traction, respectively). If Cambodia study per diem were used in our analysis, the total cost would be $780.6 for nailing and $988 for traction.

The additional costs for IM nailing were the costs of surgical implants and operating room personnel. Surgical implants, which represented 23% of the total cost, were manufactured and donated by a philanthropic organization. Although the manufacturing cost of the donated implant was included in the analysis to provide a health-system's perspective, many commercially available nails are more costly to manufacture and even more costly to purchase from a patient's or hospital's perspective.

A study done in Tanzania [23] estimated the procedure personnel cost for IM nailing to be $106, a finding that is significantly higher than our estimates of $24. There are two main reasons for this difference: first, the reported annual salaries of medical personnel in Tanzania are almost twice those in Malawi. Second, there were differences in personnel cadres involved in the procedure. In Tanzania, the staff included anesthesiologists and nurse anesthetists (20% of the personnel cost), while in Malawi anesthesia is mostly done by ACOs, which significantly reduces the personnel cost. This illustrates potential benefits of task-shifting, which is prevalent in Malawi [34].

There were several limitations to our study. First, it was conducted at one hospital, and this limits the external validity of the findings. However, QECH is the main teaching hospital in Malawi and serves as a model for the three remaining central hospitals. Second, we were not able to evaluate the costs associated with follow-up visits or

complications. Complications such as chronic osteomyelitis can result in permanent disability and require multiple surgeries, which further increases the cost. Thus, studies assessing the costs of managing complications of both interventions are warranted. Finally, we did not include the indirect costs of transportation and lost productivity for the patient or their family members, who typically provide care for the duration of the hospital stay. Although not directly measured in this study, we would anticipate that these costs would only strengthen the findings of this study.

It is important to note this study did not assess the effectiveness of either intervention by monitoring clinical outcomes. It is therefore simply a cost-analysis, rather than a true cost-effectiveness analysis. However, there is a general consensus that IM nailing results in higher rates of union, quicker recovery, and lower rates of complication [9, 17, 35, 36]. Therefore, based on our findings we would anticipate that IM nailing would be the dominant intervention in a true cost-effectiveness analysis: both better and cheaper.

Conclusion

Costs of treatment for femoral shaft fractures are largely driven by personnel, overhead and length of stay. Despite delays from injury to surgical treatment, IM nailing was cost-saving compared to skeletal traction. When possible, transferring traction patients to IM nailing up to 3-week post-admission is cost-saving compared to continuing the course of traction treatment. These findings suggest that governments, hospitals and other stakeholders should make an effort to increase access to surgical treatment for femoral shaft fractures in settings where skeletal traction remains commonplace.

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Appendix A: equations

Equation 1: procedure personnel cost

$$\text{Total procedure personnel cost} = \sum(\text{Personnel hour} \times \text{hourly wage})$$

Hourly wage was calculated by dividing the mean annual salary by 2259, the product of 9 h day and 251 working days per year (365—104 weekend days—10 holidays).

Equation 2: ward personnel cost

$$\text{Ward personnel cost} = \left(\sum_{i=1}^{n}\frac{\text{Wd} \times 9}{N}\right) + \left(\sum_{i=1}^{n}\frac{\text{Wn} \times 15}{N}\right)$$

Wd is the day shift personnel hourly wage, 9 is the day shift number of hours, Wn is the night shift personnel hourly wage. 15 is the night shift number of hours, and N is the average number of patients per day.

Equation 3: instrument set cost

$$\text{Instrument cost} = \frac{\text{Annual depreciation value} \times \text{the number of sets}}{\text{number of procedures per year}}$$

- Annual depreciation value = initial cost/useful life span.
- The IM nail instrument sets cost = \$9075. The average annual number of IM nailing operations was 89, and there was one set available at the time of the study.
- Traction pins and the manual hand drill cost = \$468/100 pins.
- Life span of 10 years was used.

Equation 4: overhead cost

$$\text{Overhead cost per patient} \times \left(\frac{(\text{Sum of annual overhead cost} \div 365)}{\text{total number of inpatient days}}\right) \times \text{length of stay}$$

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