CURRENT CONCEPTS REVIEW

How Much Does an Infected Fracture Cost?

Olivia O'Connor, BA [1,2*]; Azeem Thahir, MRCS [1]; Matija Krkovic, PhD [1]

Research performed at Department of Trauma and Orthopaedics, Addenbrookes Major Trauma Unit, Cambridge University Hospitals, United Kingdom

Received: 30 November 2020 *Accepted: 02 June 2021*

Abstract

Though infection is a common and costly complication following fracture, there is a scarcity of literature focused on the additional cost of healthcare when a fracture becomes infected. This literature review compiles existing heterogenous data to evaluate the cost of infected fractures, yielding an estimate of a 1.2-fold to six-fold increase in healthcare costs associated with infection. The increases in cost were largely driven by an increased length of stay. Factors which affect this increase include the infectious agent, the depth of infection and the location of the fracture. In order to reduce healthcare costs, early soft tissue cover and prophylactic antibiotics are effective in that they reduce the infection rates. An alternative approach is to reduce the length of stay, the key driver of cost, for example by reducing the length of inpatient antibiotic therapy. Further cost-utility analyses which focus on the same aspects of the healthcare costs are required for a more accurate estimation of the cost.

Level of evidence: IV

Keywords: Health economics, Healthcare costs, Surgical Site infection, Post-Traumatic Osteomyelitis, Open Fracture

Introduction

Resource allocation in health care systems across the world presents a major public policy issue, inciting widespread political debate and necessitating extensive consideration on how to cost-effectively treat disease. Surgical site infections (SSIs) account for $3 billion of healthcare costs per year in the US, with a large proportion of these costs attributable to longer hospitalisations and readmissions(1,2).

The risk of developing SSIs varies across specialties, with orthopaedic trauma demonstrating higher rates of SSI than many other surgical specialities(3). The SSI rate in closed fractures is 2-5%, but in open fractures, the loss of a skin barrier increases this rate to 50% due to an increased susceptibility to contamination both at the time of injury as well and during hospitalisation (4). With this high rate of SSI and the considerable economic burden of such infections, it is striking that there is a paucity of cost-utility analyses in orthopaedic trauma, with very few papers focusing on the economic burden of infection following fracture (5). The literature that does exist is heterogenous with cost analyses spanning different health care systems worldwide and focusing on different components making up the total cost of an infected fracture.

This literature review aims to compile existing evidence to provide an estimate of the additional costs of infected fractures when compared to non-infected controls, as well as discussing factors that will increase the costs further and providing suggestions on how to alleviate the economic burden. Costs of SSIs and cases of post-traumatic osteomyelitis (infection of the bone secondary to both open and closed fractures) are considered.

Materials and Methods

The preliminary literature search was performed on the PubMed database in June 2020. The literature search used the following terms (with synonyms and closely related words): "infection" combined with "fracture" and "cost". After the title screen 15 relevant papers were identified, 8 of which were identified in the abstract screen to include data on the cost of fractures with and without infection [Table 1]. The reference lists of studies selected for inclusion were scanned for relevant studies.

Corresponding Author: Olivia O'Connor, *Department of Trauma and Orthopaedics, Addenbrookes Major Trauma Unit, Cambridge University Hospitals, Hills Road, Cambridge, CB2 0QQ, United Kingdom*

Email: oo262@cam.ac.uk

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Table 1. Reported Healthcare Costs in Patients with Infected Fractures

Paper	Number of Patients	Fracture Site	Fracture Type	Infection Type	Total Cost per Patient (reported costs for control patients)	Cost Breakdown (reported costs for control patients)
Pollard et al., 2006 (6)	61	Proximal Femur	-	Deep Surgical Site Infection	£24,410 (£7,210)	-
Edwards et al., 2008 (9)	80	Hip	-	41 Deep Surgical Site Infection, 39 Superficial	£25,940 (£12,163)	• Acute stay (including HDU, ITU)- £21,212.66 (£6,915.22) • Operative- £3,539.58 (1,874.36) • Investigations- £674.21 (£188.98) • Antibiotic treatment- £513.99 (N/A)
Thakore et al., 2015 (12)	78	19 hip, 5 upper extremity, 54 lower extremity	41 closed, 37 open	Surgical Site Infection	$108,782 ($57,418)	• Professional fees • Surgical-$13,475 ($8,120) • Radiology- $718 ($524) • Evaluation and management-$1142 ($653) • Technical charges • Diagnostic- $10,718 ($6,999) • Room and board- $5,928 ($2,742) • Surgical/implant- $39,502 ($21874) • Pharmacy- $15,801 ($7,091)
Olesen et al., 2017 (4)	45	Tibia	Open	Surgical Site Infection	€93,469 (€58,612)	• Direct- €81,155 (€49,817) • Unemployment benefits- €12,314 (€8,795)
Hoekstra et al., 2017 (10); Metsemakers et al., 2017 (11)	12	Tibia	7 Open, 5 closed	Deep Surgical Site Infection	€48,702 (€9,566)	• Professional Charges- €5,536 (€1,596) • Hospitalisation- €22,185 (€2,876) • Day-care stay- €14 (€0) • Materials- €2,225 (€1,065) • Pharmaceuticals- €5,283 (€1,029)
Parker et al., 2018 (14)	35	Lower Limb	Open	Deep Surgical Site Infection	£17,513.93 (£14,704.08)	• Hospital Inpatient care - £15,445.53 (£12,796.72) • Medications- £156.91 (£90.35) • Hospital outpatient/community care- £2,858.82 (£2,436.81)
Jiang et al., 2020 (15)	278	124 tibia, 53 femur, 30 calcaneus	183 open, 95 closed	Extremity post-traumatic osteomyelitis	$10,504 ($2,189)	• Service- $318 • Diagnosis- $539 • Treatment- $1,008 • Materials- $6,480 • Pharmaceuticals- $1,027 • Miscellaneous (rehabilitation, blood products)- $538

Results

The general consensus from papers addressing the healthcare costs in infected fractures is that hospitalisation costs make the most significant contribution to the total cost regardless of position of fracture, type of fracture, type of infection or country of study [Table 1]. The length of stay is proportional the overall healthcare costs.

Proximal Femoral Fractures with SSI

With patients developing a deep SSI subsequent to a proximal femoral fracture (PFF), the mean financial cost of treatment was £24,410(6). When compared to a control group (comprised of two patients without infection matched to every patient with infection) in which the mean cost of treatment was £7,210 (IQR £4,290-£10,780), infection is shown to triple the treatment costs. Further, if those who died during treatment were excluded, the mean cost of treating patients with infection rose to £31,940 (IQR £19,460-£44,800), which is quadruple that of treating uninfected fractures. Of this increase in cost, 59% was due to increased trauma unit length of stay, 20% was due to the cost of surgical debridement and 19% was due to increased community care and rehabilitation costs. Previous studies corroborated the findings that complications following PFF surgery increased financial costs, driven largely by an increased length of hospital stay (7,8). However, these papers reported a two to 2.5-fold increase, as compared to the three-fold increase in cost when looking at infection alone, suggesting that treatment of a deep infection is more expensive than the treatment of other complications reported after the surgery, such as loosening and dislocation.

Hip Fractures with SSI

With patients who developed an SSI after hip fracture, the mean cost of treatment up until hospital discharge was calculated at £25,940 (£4,387-£93,976; n=80), while non-infected patients had a mean cost of £8,879 (£3,450-£72,564) (9). The increases in cost were attributed to significant increases in the length of stay, which made up 82% of the total cost. Operative costs added 13%. SSI doubled the operative costs, tripled the costs of investigations and quadrupled the ward costs.

Tibial Fractures with SSI

In patients with severe open tibial fractures treated with a free flap, there was a 63% increase in the direct costs with SSI, from €49,817 to €81,155 (4). There was also an increase of 40% in the unemployment benefits afforded to those with infection at €12,314 as opposed to €8,795in those without infection.

Another study showed that open tibial fractures showed a five-fold increase in the total healthcare costs (€48,702 [€28,383-€71,409] vs. €9,566 [€6,781-€15,094]) and a six-fold increase of total length of stay (60 vs. 10 days) in patients with a deep infection vs. without deep infection (10). Hospitalisation costs were the greatest of the categories analysed and after exclusion of all the process variables related to hospital stay, deep infection was identified as the most important clinical parameter driving the length of stay and therefore healthcare costs. A subset of these patients with infection underwent fracture fixation, and the calculated median total healthcare cost for patients with a deep infection was 6.5 times higher than that for uninfected patients (€44,468 [€13,574–€71,125] vs. €6,855 [€4,899–€10,495]). Of the increase in cost, 62% was due to hospitalisation, and length of stay was increased significantly to 54 days over three admissions compared to seven days without infection(11).

Fractures of Unspecified Location with SSI

SSIs were matched one-to-one with control patients in 78 patients who developed no complications after fracture(12). Patients were matched based on the National Nosocomial Infections Surveillance (NNIS) risk index which takes into account the type of wound, location and the duration of surgery. The patients had fractures of the hip, lower and upper extremities. Infected patients incurred greater costs than uninfected patients across all categories listed in Table 1. The median cost for treatment during initial hospitalisation and first readmission for an infected patient was $108,782 (IQR $61,841-$150,972) compared to $57,418 (IQR $43,333-$77,667) for an uninfected patient. The mean length of stay for these patients was increased from three to seven days due to infection. The cost breakdown showed that over 80% of the costs for both those infected and uninfected were technical costs (pharmaceuticals, room and board and diagnostic costs) as opposed to professional fees. The greatest difference in costs between the groups was in the surgical materials and anaesthesia category ($1,417,162 for all patients over the 5-year course of the study). Overall, the total additional cost of treating SSIs over the 5-year period was $4,593,874. Another paper using similar methods (matching 59 patients with infections one-to-one with patients without infections using the NNIS risk index) showed a larger 300% increase in costs, as opposed to 90%, and a larger prolongation of hospital stay of two weeks, as opposed to for days (13). However, only a small proportion of the patients in this study has fractures, which may indicate that the economic implications of SSI are less following trauma than other types of orthopaedic procedures.

A paper analysing the patient data from the WOLFF trial explored the cost of deep SSIs after an open lower limb fracture (14). Using 2015 UK tariffs, it showed that in 35 patients who developed a deep SSI, the mean costs were significantly different in the period 3-6 months post-randomisation, largely due to the significant difference in the cost of inpatient care. The mean cost of inpatient care for those with infection was £2,692 (£0-£21,629) in this period compared to £691 (£0-£10,651) for those without infection. This is in keeping with the above papers which suggest the length of stay is the most important driver of cost, and the difference may be due to an increased incidence of readmission of patients with infection in this period.

Which Factors Affect the Cost of Treating a Fracture with an SSI?

MRSA Infections

The type of organism causing the SSI can affect the cost of treatment. MRSA infections were shown to be significantly more expensive to treat than non-MRSA cases (£30,070 per case [IQR £17,190-£46,470] vs. £17,540 per case [IQR £12,370-£29,250]) (6). Of this additional cost, 51% was accounted for by increased trauma unit length of stay, 36% by increased community care and rehabilitation, and 13% by increased cost of debridement and antibiotics. Another study reported that deep SSIs caused by MRSA showed an increased cost compared to non-MRSA deep SSIs (£38,464 vs. £31,164). This increased cost was hypothesised to be due to the cost of antibiotics used or the cost of treating the side effects of the antibiotics (9).

Deep vs Superficial Infections

Regardless of the infective organism, the treatment of deep SSI was shown to cost more than the treatment of superficial SSI. In a paper reporting the mean cost of treating infected SSIs as £25,940 (£4,387-£93,976), the mean for a deep SSI was £34,903 (9). The SSI was considered to be deep if, at surgery, it was deep to the deep fascia, if the wound was left open or drained or if there was radiological evidence of infection. The cost for a deep SSI was more than double the mean cost for a superficial SSI, £16,569. The increased costs were again attributable to the increases in length of stay. The mean length of stay for a patient with no SSI after hip fracture was reported as 22 days, increasing to 50 days for a patient with a superficial SSI and 100 days for a patient with a deep SSI.

Location of Fracture

Fracture Location can affect the cost of treating an infected fracture [Table 2]. Compiling data and using the average cost per patient for each fracture location, it was shown that treating an infected tibial fracture had the highest average absolute cost (€84,044) with a 75% increase in cost when compared to treating an uninfected tibial fracture. However, the location with highest increase in cost with infection was the femur, with an increase of 239%.

Table 2. Average Costs of Treating Fracture with and without Infection based on Anatomical Location

Location of Fracture	Cost of Treating Fracture with Surgical Site Infection	Cost of Treating Fracture with Post-Traumatic Osteomyelitis	Cost of Treating Uninfected Fracture
Femur	£24,410	$14,216	£7,210
Hip	£25,940	-	£12,163
Tibia	€84,044	$13,755	€48,286
Calcaneal	-	$5,763	-

High Energy vs Low Energy Fractures

High energy fractures cost almost twice as much to treat as low energy injuries (€63,022 vs € 32,614). However, the percentage increase in the cost of treatment when an infection occurred was not significantly different between the two groups with a 54% increase to £50,168 in low-energy fractures and 43 % increase to £90,236 in high-energy fractures (4).

Post Traumatic Osteomyelitis

Post traumatic osteomyelitis occurs as a complication of more than 30% of open fractures and 1-2% of closed fractures (15). The total hospitalisation costs for 278 patients who developed post-traumatic osteomyelitis were $3,524,668 over a median length of stay of 22 days. Of the six analysed cost categories, materials were the largest driver (61%), followed by pharmaceuticals (12%), treatment (11%), miscellaneous expenses (rehabilitation, blood and blood products) (7%), diagnosis (5%), and service (4%). The median cost of treatment for post-traumatic osteomyelitis inpatients was 4.8-fold higher than control patients.

Which Factors Affect the Cost of Treating a Fracture Complicated by Post-Traumatic Osteomyelitis?

Fracture Location

Statistical differences were found in the number of hospital admissions, the length of stay and total health care costs among the three most commonly occurring fracture sites in the paper, with total median costs of $13,755 ($7,640-$19,315), $14,216 ($8,754-$23,579), and $5673 ($2,792-$7,591) for tibial, femoral, and calcaneal osteomyelitis, respectively [Table 2].

Open vs Closed Fracture

With regard to injury type, the paper found that the inpatients with post-traumatic osteomyelitis after open fractures had statistically more hospital admissions, a longer length of stay and a higher total cost ($12,890 [$5,576-$19,719] vs $8,087 [$4,380-$14,060]) than those with a medical history of closed fractures. Open fractures are more likely to result in infection due to the loss of the skin barrier, but regardless of the incidence of infection, the increased treatment costs in open fractures likely reflects the severity or extent of the infection.

Type of Fixation Used

Inpatients with post-traumatic osteomyelitis using an external fixator incurred a significantly increased number of hospital admissions, a longer length of stay and a higher cost for every analysed cost category than those not using an external fixator. Although no significant differences were found regarding the number of hospital admissions and length of stay between those using a ring fixator and those using a rail fixator, those using a ring fixator incurred a statistically higher cost than those using a rail fixator ($19,563 [$17,882-$28,231] vs. $14,966 [$12,156-$19,910]).

Discussion

A key principle in decreasing the economic burden of infected fractures is prevention rather than treatment. Prophylactic antibiotic beads have been shown to be a cost-effective way to reduce the infection rate in open fractures. In a series of 125 patients with open fractures, 3.2% got infected when treated with antibiotic impregnated beads costing $419.36 per patient (16). In other studies, the rate of SSI following open fracture has been reported as up to 50% and considering the aforementioned costs of infected fractures as compared to uninfected fractures, early spending on antibiotic beads may prevent much larger costs being incurred due to subsequent treatment of infection (17,18). For example, using the highest estimate of the cost of treating an infected fracture and the highest estimated fracture infection rate of 50%, the total costs for treating 78 patients would be $6,481,800 (12). If using antibiotic prophylaxis decreases the rate to 3.2%, then the cost for the 78 patients (including the cost of antibiotics) would be $4,639,519. This represents an average reduction in cost of $23,619 per patient when antibiotic prophylaxis is used.

Additionally, combining antibiotic-loaded calcium sulfate to generate a synergistic effect with antibiotic beads may be cost effective when treating infection. When comparing the effect of vancomycin loaded PMMA spacers with vancomycin loaded calcium sulfate 92% of infections were eradicated compared to 64% with PMMA alone (19). Calcium sulfate is relatively inexpensive ($655/10ml), though more explicit research is required to evaluate the cost-effectiveness of antibiotic-loaded calcium sulfate (20).

A second method of prevention highlighted by the literature is early soft tissue cover after open fracture. Infection rates are increased with a longer length of time before free flap receipt. With earlier surgery, the infection rate was reduced from 48% to 27%, which would have saved on average €10,840 per patient(4). Using an approximation of 100,000 new infected fractures per year in the USA, this reduction in cost would save over € 1.75 billion per year.

As stated above, increased length of stay is a major driver of the increased treatment costs for infected fractures. Therefore, reducing the length of stay will reduce the costs. One reason that a patient may need to stay in hospital is the administration of IV antibiotics. Infection in open fractures was shown to be related to the extent of tissue damage, not the duration of prophylactic antibiotic therapy, and a short duration of antibiotic prophylaxis in open fractures did not enhance the risk of subsequent infection(21). Thus, one possibility to reduce treatment costs is to shorten the duration of antibiotic therapy. Alternatively, outpatient parenteral antibiotic therapy (OPAT) could be considered(22).

Though it had been previously suggested in a small trial that Negative Pressure Wound Therapy (NPWT) dressings conferred a reduction in the rate of deep SSI, NPWT was shown to have no clinical or economic benefit to patients with open fractures of the lower limb in the larger WOLFF study (23) (24). NPWT did not reduce the cost of treatment, and it was associated with a low probability of cost-effectiveness since it made little difference to the rate of deep SSI (7.1% with NPWT vs. 8.1% without) and superficial SSI (14.8% vs. 15.5%) following open fracture.

Limitations

It is difficult to accurately estimate the cost of an infected fracture due to the sparsity of high-quality data that exists regarding cost analysis of orthopaedic trauma(5). Current analyses are often heterogenous and the available evidence is variable, meaning it is difficult to compare the cost breakdowns. The costs are based on different national healthcare financing systems according to the authors' area of study, and thus it is difficult to make conclusions based on individual papers which are generalisable to other countries.

There is no evidence to justify the treatment of complex open fractures (Gustilo – Anderson 3B and 3C) with an Intramedullary nail which is cheaper initially and then accept the complications which are costly rather than treating them with Fine wires (external fixation) which is initially expensive.

Additionally, all of the papers are likely to be underestimates of the true cost of an infected fracture; for instance, one paper did not look at follow-up costs beyond 12 months (14), while another only looked at the initial hospitalisation and one subsequent readmission (12). Only one paper looked at indirect costs to the state, such as increased unemployment benefits, after infected fracture (4)Additionally, the long-term costs of post-traumatic osteomyelitis were not evaluated. Chronic osteomyelitis can elevate the risk of many other diseases such as atrial fibrillation, diabetes mellitus and depression which will drive the healthcare costs secondary to infection resulting from fracture even higher (15). Thus, it is important to view the figures outlined in this review as conservative estimates of the true cost of an infected fracture.

Conclusions

Infection is an expensive and often preventable complication following fracture which has no fixed price to it. With infection, the cost of treating a fracture increases between 1.2-fold and 6.5-fold depending on the site of fracture, the type of infection, the cost-analysis methods utilised and the healthcare system under which the patient is being treated. Of the fractures with SSIs, tibial fractures were the most expensive to treat though of those with post-traumatic osteomyelitis, femoral fractures were the most expensive. The key driver of the increased costs was the increased period of hospitalisation for patients with infections, and hence a key principle for reducing costs may be to reduce the length of stay. However, antibiotic prophylaxis was the most cost-effective intervention discussed, with potential savings of more than $20,000 per patient when used showing that prevention of infection in all open and closed fractures may have the largest financial impact. It is difficult to obtain a more accurate estimate of the additional cost due to infection due the heterogeneity of existing literature which measures different cost categories over variable time periods. We believe that the best way is get clear information is to review cases from one health system.

Acknowledgements

Funding: No funding was received for conducting this study.

Conflicts of interest/Competing interests: The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethics approval: Not applicable

Consent to participate: Not applicable

Consent for publication: Not applicable

Availability of data and material: Not applicable

Code availability: Not applicable

Olivia O'Connor BA [1,2]
Azeem Thahir MRCS [1]
Matija Krkovic PhD [1]
1 Department of Trauma and Orthopaedics, Addenbrookes Major Trauma Unit, Cambridge University Hospitals, Hills Road, Cambridge, CB2 0QQ, United Kingdom
2 School of Clinical Medicine, University of Cambridge, CB2 0SP, United Kingdom

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