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Clinical Study

Surgical versus nonsurgical treatment of thoracolumbar burst fractures in neurologically intact patients: a cost-utility analysis

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Abstract

BACKGROUND CONTEXT: Many efforts have been made to determine what is the best treatment strategy for neurologically intact patients with TL burst fractures: surgery or nonoperative management. Studies comparing clinical outcomes have produced mixed and inconclusive results creating lack of consensus in the expert community.

PURPOSE: Therefore, it is necessary to explore other important components of healthcare such as economics to settle this controversial debate. The goal of the current study was to perform a cost-utility analysis comparing surgical treatment to nonoperative treatment for neurologically intact TL burst fractures (AOSpine classification types A3 and A4) from a societal perspective in a multicenter and international setting.

STUDY DESIGN/SETTING: We performed a cost-utility analysis from a societal perspective comparing the cost-utility of surgical treatment versus nonsurgical treatment of thoracolumbar (TL) burst fractures in neurologically intact patients.

PATIENT SAMPLE: Patient demographics and all clinical and outcome data were taken from an observational, prospective multicenter cohort study comparing surgical versus nonsurgical treatment of TL burst fractures in neurological intact patients.

OUTCOME MEASURES: The ICER was calculated comparing surgical versus nonsurgical treatment for the full analysis population with a 1-year time horizon, two-year time horizon as well as the working-life time horizon. Costs were taken from the clinical study, patient diaries with productivity loss documented, current scientific literature in addition to national and international healthcare costing guidelines and databases.

METHODS: The mean difference in cost between the two treatment groups were calculated, firstly by applying the central limit theorem, and secondly by using bootstrapping. To calculate the average cost per patient in each treatment group, the Kaplan-Meier Sample Average (KMSA) estimator was used in order to take account of the censored patients. To evaluate the derived models and to explore uncertainty, sensitivity analysis was used.

RESULTS: Eleven sites from different regions (North America, Europe, Middle east, and Asia) completed the recruitment and follow-up for 213 patients. One hundred and thirty patients were treated surgically (61.0%) and eighty-three patients (39.0%) were treated nonsurgically. At 1-year, the ICER for surgical treatment was $191,648.00 USD per QALY. Compared to a willingness to pay threshold of $100,000, surgical treatment was not cost-effective within the 1-year timeframe. At 2-years, the nonsurgical group had visited the surgeon or general practitioner more often (0.31 vs 0.25). The nonsurgical group had visited physiotherapist and other allied health more often (3.68 vs 1.68). The utilization of NSAIDs and opioids remained higher in the nonsurgical group (2.66 vs 2.39) (1.52 vs 0.75). The average workdays lost remained higher in the nonsurgical group (143.12 vs 114.78). The caregiver days taken off work remained higher in the nonsurgical group (29.86 vs 2.39). At 2 years, surgical treatment showed to be a dominant strategy with a $28,978.50 savings per QALY. At lifetime horizon, surgical treatment remained the cost-effective strategy at $25,530.18 savings per QALY.

CONCLUSION: Our cost-utility analysis showed surgical management to be cost-effective at 2 years compared to nonoperative management in neurologically intact TL burst fractures from a societal perspective. This finding was maintained through the working-lifetime horizon. Surgical treatment became cost-effective largely due to the greater productivity loss of patients and caregivers within the nonsurgical group. This investigation highlights the viability for surgical management of TL burst fractures to provide societal benefit especially when productivity is valued.

Keywords: Thoracolumbar; Burst; Fractures; Neurologically intact; Societal perspective; Cost-utility analysis

Introduction

Thoracolumbar (TL) burst fractures often occur under traumatic axial load with failure of the anterior column [1]. According to the AO Spine TL Classification System, TL burst fractures would classify as compression injuries with failure of anterior structures with an intact tension band corresponding to type A [2]. TL burst fractures in neurologically intact patients account for approximately 45% of all TL spine injuries [3−5]. Thoracolumbar trauma is a common pathology with a significant burden to patients and society. In an epidemiological study by Hu et al in North America, the incidence of spinal injuries is more than 160,000 every year, and in Canada it was 64/100,000 population/year [6].

Many efforts have been made to determine what is the best treatment strategy for TL burst fractures in neurologically intact patients: surgery or nonoperative management [3,4,7−10]. Studies comparing clinical outcomes have produced mixed and inconclusive results creating lack of consensus in the expert community. Additionally, the opinions of surgeons worldwide are divided regarding the best management for this pathology. Different schools of thoughts exist worldwide advocating either for surgical or nonsurgical treatment based on local expertise. With this lack of consensus, a critical knowledge gap exists in the spinal surgery community as well as in the current available literature. Therefore, it is primordial to explore all important components of healthcare such as economics that may settle this controversial and ongoing debate.

It has been reported that the costs per patient related to vertebral column injuries is higher compared with other types of injuries [11]. In North America, 2% to 23% of all trauma admissions are related to acute spinal trauma [12]. Given this burden on the healthcare system, it is primordial to explore economic data to determine which treatment strategy is most cost-effective. This will allow better resources allocation in a world where most healthcare systems are already under strain. This is particularly important given that both alternatives, surgery and nonoperative management, have so far been proven to be equivalent from a clinical point of view creating an ongoing controversy and deliberation.

Studies analysing health economics have generally shown that the cost of surgery and hospitalization are the main cost drivers [5,13−15]. However, few studies have approached the issue from a societal perspective and few have taken into account indirect costs. Considering intangible costs related to pain and suffering is especially important in this population as TL burst fractures occur in a young and active population in their prime productive working years. It is essential to conduct an economic analysis from a societal perspective accounting for healthcare utilization, productivity loss and its impact on patients and society. It is possible that indirect costs associated with nonoperative management balance or outweight the direct costs associated with surgery. This has not been studied yet and it a critical question that remains to be answered. Additionally, most available studies reporting cost have small sample sizes, are single-center and lack global representation. To solve this global ongoing debate regarding best treatment strategy for TL burst fractures, it is crucial to encompass a wide representation of practices from vast geographical regions. This would allow the results and recommendations to be generalizable worldwide and impact health policy decision-making globally.

The goal of the current study was to perform a cost-utility analysis comparing surgical treatment to nonoperative treatment for neurologically intact TL burst fractures (AOSpine classification types A3 and A4) from a societal perspective. We aimed to perform this analysis in a multicenter and international setting where costing is completed in the same methods and reference values.

Methods

Study design

We performed a cost-utility analysis from a societal perspective comparing the cost-utility of surgical treatment versus nonsurgical treatment of thoracolumbar (TL) burst fractures (A3 and A4) in neurologically intact patients. The societal perspective counts for all benefits and costs for the basis for fair decisions in the public interest with all resources to be identified, measured and valued [16].

Primarily, a cost-utility analysis was determined for a 1-year time horizon, followed by 2-year and lifetime time horizon. The lifetime time horizon was defined as the as a working-life time horizon, ie, a time horizon of 24 years based on the average age of the patients included in the study, expecting a retirement by the age of 65. Lastly, a cost-utility analysis was performed with a 1-year time horizon in Europe and North America. Event rates and utilities for Asia, India and the Middle East were considered in Europe, but costing was only considered from the European countries. Australia was considered for North America, but costing was only considered from the North American countries.

Patient demographics and all clinical and outcome data were taken from the observational, prospective multicenter cohort study comparing surgical versus nonsurgical treatment of TL burst fractures in neurological intact patients (*An observational, multicenter cohort study comparing surgical versus nonsurgical treatment*, ClinicalTrials.gov: NCT02827214). Each enrolling center obtained local approval from their local institutional review board. The full study details are available in the adjacent publication. The inclusion and exclusion criteria for the economic analysis mirrored that of the cohort study. In summary, adult patients with acute closed thoracolumbar burst fractures AO type A3 and A4 from T10 to L2 with or without suspected PLC injury were included in this study. Patients were excluded if there was any neurological deficits, pathologic processes or neoplasia, previous surgery or polytrauma.

All presented analyses were performed using the full analysis population, ie, all patients who provided a signed informed consent and commenced treatment within the study. For the design, analysis, and publication of the study no patient or public representatives were involved.

Treatment

The surgical/nonsurgical procedure(s)/study procedure (s) were per standard of care at each institution and at the discretion of the treating surgeon. Nonsurgical treatment was defined as pain management, early mobilization or bed rest if deemed necessary by the treating surgeon with or without following external immobilization. External immobilization included thermoplastaic removable brace, Jewett hyperextension brace, anterior hyperextension brace, Taylor-Knight brace, TLSO and other braces for comfort. Surgical Treatment included open or percutaneous instrumentation with or without fusion with short (1 level above or below the fracture) or long (2 or more levels above or below) instrumentation. Surgical treatment included anterior reconstruction or posterior only fixation.

Resource utilization and costing

Costs were obtained from study sites and current scientific literature. The average wage of participating countries was obtained from the scientific literature and national databases. This data was used to determine cost due to loss of productivity and caregiver care. Costs were obtained for each region that participated in the cohort study, but analysis were presented in US dollars (USD). Cost per patient was calculated using resource utilization costs and unit costs for resources.

Each participant use of in-hospital, as well as 1- and 2-year health care resource utilization (direct costs) data were taken from the clinical study, including the information about the surgical and nonsurgical treatment, length of hospital, emergency room and physician visits, diagnostic tests, physical therapy, pain medication and antibiotics and care giver days. Pain medications were recorded as the number of prescriptions filled. The dose or quantity was not available.

For the indirect costs, patients were asked to fill in a patient diary, containing the Indirect Cost Questionnaire, in which any productivity loss was documented (Appendix 1). The following data was collected: whether back pain stopped return to work (yes/no), time to return to work, return to same job/occupation, the level of physicality of the current employment, unplanned medical treatments and its frequency, oral medications, need for help from a caregiver, caregiver time off work, and patient gross salary per year. The patient diary was completed by the patients starting at week 2 or at discharge (whatever came first) and was then completed every second week until 6-month follow-up. Afterwards, the patients were asked to fill in the patient diary every 2 month until the 2-year follow-up. The productivity losses, ie, the absent time from work, was determined based on the missed work days of the patients, any changes in employment activities, as well as the number of missed work days for a patient's caregiver. Patient diaries also captured medications used in the follow-up period.

The overall diary response rate was 88%. When missing data ruled out calculation of inpatient or outpatient resource utilization, multiple imputation was completed using country-specific utilization values for that item within the group study sample. If these data were not available in the sample, then we obtained values from the literature.

Direct and indirect costs data were also taken from current scientific literature in addition to national and international healthcare costing guidelines and databases and for the different healthcare resources utilized as well as the costs for caregiver care and cost of lost wages calculated (Table 1). All unit costs were converted into USD 2019 values using the CCEMG − EPPI − Centre Cost Converter v1.6. It is a free web-based software for adjusting estimates of cost expressed in 1 currency and price year to a specific target currency and price year [17].

Utilities

The EQ-5D-3 L utility scores obtained from patients in the clinical study were converted to quality adjusted life years (QALYs) by multiplying a person's life expectancy by the value of the Quality of Life (QoL) experienced in each period, measured by the EQ-5D-3 L utility score [39]. The EQ-5D-3 L is a self-completed questionnaire evaluating 5 dimensions (mobility, self-care, usual activities, pain/discomfort, anxiety/depression) over 3 levels (no problems, some problems, extreme problems). Utility scores were obtained from discharge, 6 weeks, 3-, 6-, 12- and 24 months posttreatment. For missing EQ-5D-3 L scores at index level multiple imputation was conducted. Two different models were used to estimate changes in life expectancy, namely Life Table Methods and Survival Analysis.

Cost-utility analysis

Cost-utility was assessed using the Incremental Cost-Effectiveness Ratio (ICER), which is determined by calculating the difference in costs divided by the difference in QALYs between the 2 treatment groups (surgical treatment versus nonsurgical treatment) [40,41]. The mean difference in cost between the 2 treatment groups were calculated, firstly by applying the central limit theorem, and secondly by using bootstrapping. To calculate the average cost per patient in each treatment group, the Kaplan-Meier Sample Average (KMSA) estimator was used in order to take account of the censored patients. The ICER was calculated comparing surgical versus nonsurgical treatment for the full analysis population with a 1-year time horizon, 2-year time horizon as well as the working-live time horizon. Lastly, ICER was calculated to compare surgical treatment versus nonsurgical treatment in Europe and North America with a 2-year time horizon. Treatments were considered cost-effective at an incremental cost-effectiveness ratio (ICER) of 100,00 USD or less per QALY (willingness to pay) [42].

Table 1
List of unit costs by region

Resource	Region	Equivalent cost (USD)	Source(s)
Surgical procedure			
Open segment posterior fixation with/without posterior decompression	North America	11,743.59	[18]
	Europe	10,742.67	[19]
Percutaneous fixation with or without vertebroplasty, or anterior instrumentation	North America	11,040.54	[18]
	Europe	10,045.02	[19]
Hospital admission and health practitioners			
Hospital stay (per day)	North America	873.31	[20]
	Europe	708.75	[21,22]
Emergency room (per visit)	North America	208.89	[23]
	Europe	255.62	[23]
Surgeon/ General practitioner (per visit)	North America	157.51	[24]
	Europe	106.42	[22,25,26]
Physical therapy/ Occupational therapy (per visit)	North America	88.57	[27]
	Europe	35.04	[25,28]
Imaging			
Radiographs	North America	104.07	[6]
	Europe	120.96	[26,28,29]
CT Scan	North America	301.47	[21,29,30]
	Europe	293.19	[21,29,30]
Medications			
NSAIDS	North America	35.40	[31]
	Europe	16.89	[32]
Opioids	North America	79.68	[31]
	Europe	69.33	[33]
Antibiotics	North America	74.34	[34]
	Europe	41.63	[35]
TLSO Brace	North America	3719.53	[36]
	Europe	3719.53	[36]
Caregiver care (per day)	North America	188.07	[37]
	Europe	175.61	[25,28,38]
Cost of lost wages (per day)	North America	188.07	[37]
	Europe	175.61	[25,28,38]

Model structure

For the 1-year economic evaluation a decision tree model was used. For the modelling of economic evaluation at the 2-year and working-life time horizon, Markov modelling techniques were applied. Decision models were developed to consider the effect of the treatment type over the duration of a patient's entire working lifespan. A probabilistic Markov model was developed to estimate expected values for costs and QALYs for both treatment groups across these timeframes. Since no cost information is available for subjects after the conclusion of the follow-up period, we assume that costs incurred after this time are independent of the subject's treatment arm. We used the same incremental cost estimates for the working-lifetime analysis beyond the 2-year timeframe as was used for the 1-year postdischarge analysis.

Sensitivity analysis

To evaluate the derived models and to explore uncertainty, sensitivity analysis was used. One-way sensitivity analysis was conducted for the 1-year time horizon for all potentially influential model variables considered most important, imputing the plausible range of values. If the analysis is insensitive to changes in any variable within its plausible range, then the analysis can be considered as robust. To facilitate this analysis, a clinically plausible range of values for each variable were determined based on the cohort study data, relevant literature, and expert opinion. The one-way sensitivity analysis was visualized using a tornado plot. Sensitivity ranges were utilized as ± 10% to account for potential differences within each variable within the sensitivity analysis.

Unlike a one-way sensitivity analysis, a probabilistic sensitivity analysis (PSA) models the impact of joint uncertainty on all aspects of the evidence used in the model at the same time. For that purpose, values are simultaneously drawn from all distributions (using a random number generator) and the model will run, for each combination of parameter estimates, many times with the resulting cost and effect pairs being recorded. We used a Monte Carlo simulation of 100'000 runs for the PSA. PSAs were ran for the 1-year, two-year as well as the working-live time horizons.

Because utility information is not available for the study population beyond the end of follow-up, we determined the utility benefits based on a discounted rate of 3.5% for the remainder of the working-lifetime period. Costs were also discounted at the 3.5% rate per year. As the average age of patients was 41 years old, the working-lifetime horizon was, on average, 24 years long, assuming on average a retirement-age of 65 years within the study population.

Results

Population characteristics

Eleven study sites from different regions (North America, Europe, Middle east, Australia and Asia) completed the recruitment and follow-up for 213 patients. One hundred and thirty patients were treated surgically (61.0%) and 83 patients (39.0%) were treated nonsurgically (Table 2). Patient's demographics were similar between groups except race (p=.038) and nationality (p<.001). The surgical group had more Asian and less Caucasian patients (p=.038). All patients were admitted from home following the injury and were not already inpatients prior to the injury or were not transferred from another institution. Surgical patients were more likely to be from Europe, the Middle East and India, while nonsurgical patients were more commonly from North America and Australia (p=<.001) (Table 3).

Table 2
Participant Characteristics, return to work and need for revision surgery

	Surgical treatment *n*=130	Nonsurgical treatment *n*=83	p-value
Sex, n (%)			.160
Male	89 (68.46)	49 (59.04)	
Female	41 (31.54)	34 (40.96)	
Age, mean years (±SD)	40.93 (13.83)	42.77 (13.99)	.347
Body mass index (kg/m^2, ±SD)	25.23 (3.95)	25.79 (4.12)	.324
Charlston Comorbidity Index, n (%)			.646
0	121 (93.08)	76 (91.57)	
1	8 (6.15)	4 (4.82)	
2	1 (0.77)	1 (1.20)	
3	0 (0)	1 (1.20)	
4	0 (0)	1 (1.20)	
Race, n (%)			**.038**
Caucasian	100 (76.92)	73 (87.95)	
Black	0 (0)	0 (0)	
Asian	26 (20.00)	7 (8.43)	
Mixed	2 (1.54)	0 (0)	
Other	2 (1.54)	3 (3.61)	
Work status, n (%)			.055
Employed	74 (56.92)	55 (66.27)	
Self-employed	24 (18.46)	5 (6.02)	
Student	7 (5.38)	7 (8.43)	
Unemployed	8 (6.15)	7 (8.43)	
Homemaker	10 (7.69)	2 (2.41)	
Retired	7 (5.38)	7 (8.43)	
Current smoking status, n (%)			.317
Yes	24 (18.46)	11 (13.25)	
No	106 (81.54)	72 (86.75)	
Nationality, n (%)			**<.001**
American	6 (4.62)	19 (22.89)	
Australian	2 (1.54)	14 (16.87)	
Canadian	6 (4.62)	15 (18.07)	
Dutch	12 (9.23)	13 (16.87)	
Egyptian	25 (19.23)	2 (2.41)	
Swiss	18 (11.54)	1 (1.20)	
Indian	24 (18.46)	2 (2.41)	
Romanian	33 (25.38)	11 (13.25)	
Spanish	3 (2.31)	1 (1.20)	
Greek	1 (0.77)	5 (6.02)	
Preinjury residential status, n (%)			-
Home	130 (100%)	83 (100%)	
Fracture type, n (%)			**<.001**
A3	62 (47.69)	60 (72.29)	
A4	65 (50.00)	21 (25.30)	
Inability to return to work, n (%)	13 (13.54)	9 (17.31)	.84
Revision surgery, n (%)	6 (4.62)	N/A	-
Required surgery after non operative management, n (%)	N/A	3 (3.61)	-

Boldface indicates statistical significance ($p \leq 0.05$).

Table 3
Geographic distribution for treatment groups

Variable	Regions						p-value
	Europe *N*=98	North America *N*=46	India *N*=26	Middle East *N*=27	Australia *N*=16	Total *N*=213	
Treatment received, n (%)	98	46	26	27	16	213	<.001
Surgical treatment	67 (68.4)	12 (26.1)	24 (92.3)	25 (92.6)	2 (12.5)	130 (61.0)	
Nonsurgical treatment	31 (31.6)	34 (73.9)	2 (7.7)	2 (7.4)	14 (87.5)	83 (39.0)	

The surgical group had a smaller proportion of A3 fracture (47.7% vs 72.3%, p<.001) and a larger proportion of A4 fractures (50.0% vs 25.3%, p<.001). Six patients required revision surgery in the surgical group (4.6%). In the nonsurgical group, 3 patients required delayed surgery for intractable mechanical back pain and progressive deformity (3.6%). In the surgical group, 3 patients required revision surgery for instrumentation malposition (2) and nonunion (1). Three additional surgical patients had their instrumentation removed after healing. There were no deaths or major complications within the cohort during the follow-up period.

Resource utilization and cost utility at each time horizon

One-year time horizon

For the parameters included in the model at 1-year, the nonsurgical group had more visits to physical therapy and other allied health postdischarge (2.37 vs 1.34) (Table 4A). The nonsurgical group had filled more prescriptions for NSAIDs (2.17 vs 1.95) and opioids (1.27 vs 0.63), but less for other analgesics (0.80 vs 0.98). The nonsurgical group had more workdays lost compared to the surgical group (115.52 vs 95.82). The caregiver had taken more days off work in the nonsurgical group as well (14.53 vs 2.19).

The direct costs were higher in the surgical group ($15,509.25 vs $5,384.05). The indirect costs were higher in the nonsurgical group ($23,809.17 vs $ 17,516.93) (4B). The total costs were $33,026.18 for the surgical and $29,193.22 for the nonsurgical. The difference in QALY between surgical and nonsurgical was only 0.02 and the mean difference in costs was $3,832.96. Therefore, the ICER for surgical treatment was $191,648.00 USD per QALY (Table 5A). Compared to a willingness to pay threshold of $100,000, surgical treatment was not cost-effective within the 1-year timeframe.

One-way sensitivity analysis demonstrated that cost utility within 1 year could be widely variable, depending on the sensitivity variables adjusted. Due to the similarity in utility scores between groups, changes to the difference in utility scores between groups has the largest impact on the model. The parameters used in the sensitivity analysis are shown in the tornado plot representation (Fig. 1). In 1-way sensitivity analysis, the surgical direct costs potentially impacted the base case ICER by -$74,679.50 to $81,050.50. The caregiver costs potentially impacted the base case ICER from -$14,721.10 to $14,752.10.

The probabilistic sensitivity analysis (PSA) was performed using a Monte Carlo simulation of 100,000 runs (Fig. 2A). Probabilistic sensitivity analysis demonstrated a general unlikelihood of cost utility within the 1-year timeframe at a willingness to pay threshold of $100,000. Most simulations resulted in an outcome above the willingness to pay threshold, meaning that surgical treatment would not have been cost-effective in that simulation.

Two-year time horizon

For the parameters included in the model at 2-years, the nonsurgical group visited the surgeon or general practitioner more often (0.31 vs 0.25) (Table 6A). The nonsurgical group visited physiotherapist and other allied health more often (3.68 vs 1.68). The nonsurgical group filled more prescriptions for NSAIDs (2.66 vs 2.39) and opioids (1.52 vs 0.75). The surgical group filled more prescriptions for antibiotics (1.30 vs 0.07). The average workdays lost remained higher in the nonsurgical group (143.12 vs 114.78). The caregiver days taken off work remained higher in the nonsurgical group (29.86 vs 2.39).

At 2 years, indirect costs for nonsurgical patients had increased to over $10,000 more than for surgical patients ($31,560.46 vs $20,903.66) (Table 6B). These indirect costs (lost workdays and caregiver burden) led to the total cost for nonsurgical care ($37,056.19) being higher than that for surgical care ($36,476.62) and led to an ICER of -$28,978.50, ie, surgery was the dominant treatment modality (Table 5B). Simulations primarily fell below the willingness to pay threshold of $100,000, indicating that our result of cost utility for surgical treatment is robust from a societal perspective at 2 years (Fig. 2B).

Lifetime horizon

Looking at the working lifetime time horizon and only considering workdays projected to be lost and not caregiver days, the cost of surgical care (direct and indirect) was $112,497.50 while the cost of nonsurgical care increased to $121,177.76. The difference in QALY between surgical and nonsurgical was 0.34 and the mean difference in costs was -$8,680.26. Over the working lifetime, the ICER was -$25,530.18, ie, surgery remained the dominant treatment modality (Table 5C). The utility and cost benefits observed through the first two years maintained a beneficial outcome

Table 4
One-year time horizon resource utilization and cost in units per patient

A) Resource utilization		
Resource	Surgical treatment *n*=130	Nonsurgical treatment *n*=83
Health practitioners (# visits)		
Emergency room	0.09	0.06
Surgeon / General practitioner	0.21	0.20
Physical therapy / Occupational therapy / Chiropractor	1.34	2.37
Medications taken (# prescriptions filled)		
NSAIDS	1.95	2.17
Opioids	0.63	1.27
Other analgesics	0.98	0.80
Antibiotics	0.06	0.07
Other		
Custom-molded or prefabricated total body contact thoraco-lumbosacral orthosis (TLSO)	0	0.43
Other brace/immobilization	0	0.57
Caregiver care (days taken off work)	2.19	14.53
Average work days lost per patient	95.82	115.52

B) Costs		
Resource	Surgical treatment *n*=130	Nonsurgical treatment *n*=83
Screening and imaging procedures*	$413.36	$410.73
Index surgical procedure (if applicable)	$10,632.60	N/A
Hospital Admission and Health Care Practitioners		
Hospital stay	$3,388.04	$2,214.15
Emergency room	$30.16	$18.96
Surgeon / General practitioner	$136.70	$153.35
Physical therapy / Occupational therapy / Chiropractor	$54.37	$134.05
Medications		
NSAIDs	$45.57	$62.56
Opioids	$58.34	$131.47
Antibiotics	$6.70	$6.01
Other analgesics	$65.00	$66.00
Other		
Bracing	$0	$1,680.01
Caregiver care	$579.77	$2950.42
Lost productivity	$16,937.16	$20,858.75
Direct costs	$15,509.25	$5,384.05
Indirect costs	$17,516.93	$23,809.17
Total costs (direct and indirect)	$33,026.18	$29,193.22

* Estimates from the literature—not captured in study.

when discounted over the working lifetime. Simulations primarily fell below the willingness to pay threshold of $100,000, indicating that our result of cost utility for surgical treatment is robust from a societal perspective at the working-lifetime horizon (Fig. 2C).

Europe vs North America

Both the ICERs between treatment groups within North America and Europe from a 1-year time horizon were not cost-effective when compared to a willingness-to-pay threshold of $100,000 USD (Table 7). The results indicated a trend of improved cost utility within Europe compared to North America (ICER Europe=$183,099.50 vs ICER NA $206,930.50). The larger ICER in North America is explained by the larger gap between surgical and nonsurgical costs.

Discussion

This study provides new and valuable information which is crucial in settling the ongoing debate regarding best treatment for neurological intact TL burst fractures. This is the largest prospective international cost-utility analysis of thoracolumbar burst fractures from a societal perspective presenting direct and indirect costs. With its global perspective, this study uniquely considers the wide spectrum of local practices for surgical and nonsurgical treatment allowing a complete portrait of this pathology's burden on the global healthcare system. The main finding of this

Table 5
Cost-utility analysis of treatment options at 1-year, 2-year and lifetime horizon

A) 1-year horizon					
Treatment	Cost in $US Mean	Total QALYs Mean	Difference in QALY Mean	Difference in costs Mean	ICER $US/QALY
Surgical treatment	$33,026.18	0.88	0.02	$3,832.96	$191,648.00
Nonsurgical treatment	$29,193.22	0.86			

B) 2-year horizon					
Treatment	Cost in $US Mean	Total QALYs Mean	Difference in QALY Mean	Difference in Costs Mean	ICER $US/QALY
Surgical treatment	$36,476.62	1.79	0.02	−$579.57	−$28,978.50 (Dominant)
Nonsurgical treatment	$37,056.19	1.77			

C) Lifetime Horizon					
D) Treatment	Cost in $US Mean	Total QALYs Mean	Difference in QALY Mean	Difference in costs Mean	ICER $US/QALY
Surgical treatment	$112,497.50	15.85	0.34	−$8,680.26	−$25,530.18 (Dominant)
Nonsurgical treatment	$121,177.76	15.51			

Note: Lifetime Horizon determined as 24 years based on average age of patients, expecting retirement by age 65. Lifetime horizon does not include indirect costs from care giver beyond 2 years post discharge, as no cost diaries at 24 months indicated a patient was still requiring a caregiver.

study is that, by the 2-year time horizon, surgical treatment became cost-effective due to greater productivity loss and caregiver costs in the nonsurgical group. The cost-effectiveness of surgical treatment was maintained through the working life-time horizon. Surgical management should be favoured in neurologically intact TL burst fractures especially in young patients where productivity is valued.

Compared to a willingness to pay threshold of $100,000, surgical treatment was cost-effective and the dominant strategy starting at the 2-year time horizon. The ICER was -$28,978.50 lower for surgical treatment showing a trend of improved cost effectiveness that is maintained at lifetime horizon with an ICER at -$25,530.18. Simulations fell below the willingness to pay threshold of $100,000 indicating robust cost-effectiveness from a societal perspective. The difference in QALY was minimal between surgical treatment and nonsurgical treatment at 2 years (surg: 1.79 vs nonsurg: 1.77, diff: 0.02) and at lifetime horizon (15.85 vs 15.51, diff: 0.34). However, surgical treatment did remain with slighter higher QALYs than nonsurgical treatment. The cost for surgical intervention were offset largely due to the lesser productivity loss of patients (surg: $20,288.53 vs nonsurg: $25,842.32) and of caregivers (surg: $615.13 vs nonsurg: $5,718.14) as well as the need for bracing in the nonsurgical group (surg: $0 vs nonsurg: $1,680.01).

Other studies have analyzed the health economics of thoracolumbar burst fractures [1,5,13−15,43]. In line with our study, direct costs are higher for surgical management in most published reports. However, few studies have

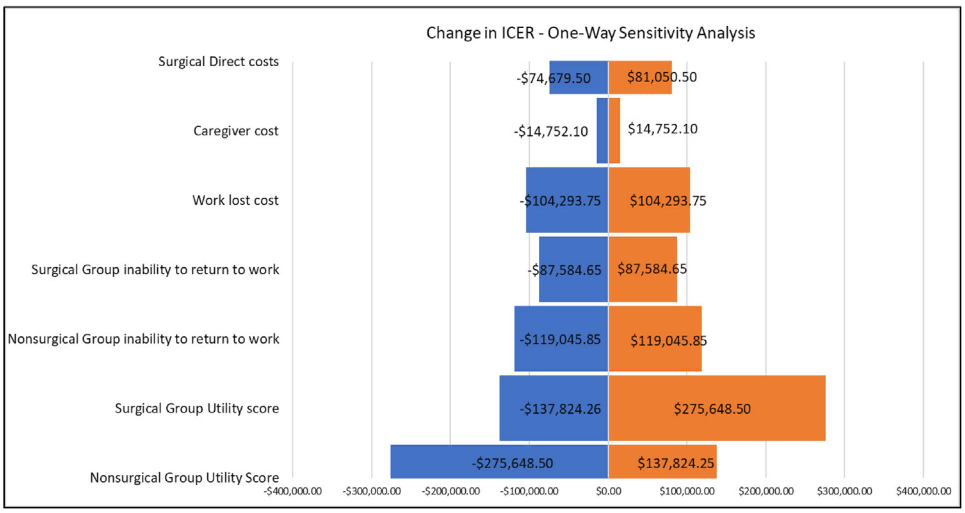

Fig. 1. Tornado plot for 1-way sensitivity analysis for 1-year time frame.

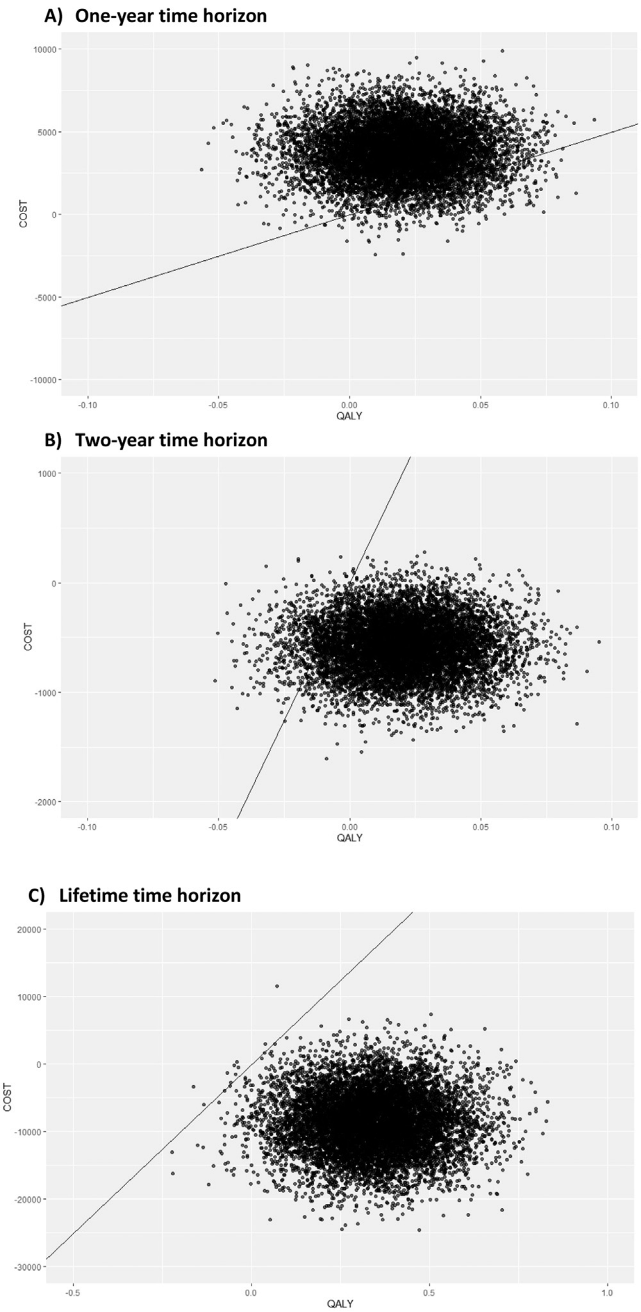

Fig. 2. Probabilistic sensitivity analysis. Values on the x axis are QALY. Values on the Y-axis are cost in USD.

considered indirect costs. Aras et al reported a cost-effectiveness analysis under the perspective of a tax-funded state-run universal health care system in Denmark [1]. That study favoured conservative management, but did not account for work performance, which is crucial in this young and active patient population. Siebenga et al presented the only other cost-effectiveness analysis from a societal perspective to our knowledge, but the sample size was rather small and from a single institution [43]. They reported 30 nonrandomized patients with 14 receiving nonsurgical treatment and 16 receiving surgery in a European institution. Mean direct costs were higher in the surgical group (US$21,960 vs US$11,880), but indirect costs were significantly lower in the surgical group (US$7,192 vs US $11,179). In their study, the surgically treated patients returned to work earlier. Indirect costs were calculated using both cost of absenteeism and cost of disablement. The average cost of absenteeism for a nonsurgical patient was $10,329 compared to $6,630 for a surgical patient. Through questionnaire, it was verified that the disablement was caused by residual back pain or was treatment related. One-hundred and fifty-nine years had to be compensated in the nonoperative group for a total of $252,128 per patient. Forty-six years had to be compensated in the surgical group for a total of $49,688 per patient. Indirect costs overall exceeded direct costs and consisted of 95.4% of the cost for patient treated nonoperatively and 71.6% of the cost of patients treated surgically. Ultimately, nonoperative management was 3.5 times most expensive. Therefore, it is possible that because of faster mobilization and shortened rehabilitation, the surgical patient may return to work earlier or at a similar timepoint, but less disabled. Consequently, on a lifetime horizon, the overall costs postinjury turns in favor of surgical therapy. Most comparative large scale clinical studies have not found a difference in the rate of return to work between surgery and nonoperative management, but those studies did not consider the cost of productivity loss or disablement for the patient and caregivers [7−9].

The nonoperative group was more disabled and utilized more healthcare resources. At 1-year and 2-year time horizon, the nonsurgical group used more NSAIDS and opioids than the nonsurgical group. The nonsurgical group also utilized more frequently allied health professionals such as physiotherapists, occupational therapists, and chiropractors. Aras et al [1] did not observe a difference in narcotics use between surgical and nonsurgical group when performing a cost-effectiveness analysis. However, opioid use was collected in oral morphine equivalent in milligrams and daily doses. Our study recorded medications as the number of prescriptions filled. It is possible that the quantities may be similar, but our results suggests that nonsurgical patients seem to be using pain medications, notably opioids, for a longer period with more prescriptions filled. Siebenga et al also presented results where resource utilization was greater in the nonsurgical group. Similarly to our study, nonsurgical patients had more visits to their general practitioner and more visits to physiotherapists. Nonoperative patients spent 500 min at the general practitioner after discharge compared to 214 min for operative patients. Other expenditures such as physiotherapy, transportation, education for job change were higher in the nonoperative group at $816 per patient compared to $550 for the surgical patient.

In this present study, the difference in QALY was minimal between the comparative groups. This is in line with previous studies comparing clinical outcomes [4,7−9]. However, defining and measuring the optimal treatment

Table 6
Two-year time horizon resource utilization and costs in units per patient by treatment group

A) Resource utilization		
Resource	Surgical treatment n=130	Nonsurgical treatment n=83
Health practitioners (# visits)		
Emergency room	0.09	0.06
Surgeon / General practitioner	0.25	0.31
Physical therapy / Occupational therapy / Chiropractor	1.68	3.68
Other specialist	0.53	0.64
Medications taken (# prescriptions filled)		
NSAIDS	2.39	2.66
Opioids	0.75	1.52
Other analgesics	1.08	1.01
Antibiotics	1.30	0.07
Other		
Caregiver care (days taken off work)	2.39	29.86
Average workdays lost per patient	114.78	143.12

B) Mean costs per participants based on units per participants		
Resource	Surgical treatment n=130	Nonsurgical treatment n=83
Screening and imaging procedures*	$413.36	$410.73
Index surgical procedure (if applicable)	$10,632.60	N/A
Hospital Admission and Health Care Practitioners		
Hospital stay	$3,388.04	$2,214.15
Emergency room	$30.16	$18.96
Surgeon / General practitioner	$141.14	$167.29
Physical therapy / Occupational therapy / Chiropractor	$67.97	$207.83
Medications		
NSAIDs	$53.75	$57.44
Opioids	$66.77	$149.83
Antibiotics	$62.06	$6.01
Other analgesics	$70.00	$76.5
Other		
Bracing	$0	$1,680.01
Caregiver care	$615.13	$5718.14
Lost productivity	$20,288.53	$25,842.32
Direct costs	$15,572.96	$5,495.73
Indirect costs	$20,903.66	$31,560.46
Total costs (direct and indirect)	$36,476.62	$37,056.19

* Estimated from the literature—not captured in study.

Table 7
Base case cost-utility analysis based on geographic region

Treatment	Cost in $US Mean	Total QALYs Mean	Difference in QALY Mean	Difference in Costs Mean	ICER $US/QALY
Overall population					
Surgical treatment	$33,026.18	0.88	0.02	$3,832.96	$191,648.00
Nonsurgical treatment	$29,193.22	0.86			
Europe					
Surgical treatment	$31,677.97	0.88	0.02	$3,661.99	$183,099.50
Nonsurgical treatment	$28,015.98	0.86			
North America					
Surgical treatment	$34,872.06	0.88	0.02	$4,138.61	$206,930.50
Nonsurgical treatment	$30,733.45	0.86			

effect in spinal trauma remains an unsolved challenge given the lack of validated instruments and the nature of the acute traumatic event. With the unknown preinjury health status, baseline measurements are often not available and relies on recall. Given the lack of consensus, a wide spectrum of outcomes are currently used from radiological outcomes, mortality and complications as well as patient reported outcomes [44]. Commonly used outcome measurement tools have not been validated in the spine trauma populations such Oswestry Disability Index, Roland Morris Disability Questionnaire, Short Form 36, EQ5D or VAS. The aforementioned tools are likely not capturing all relevant dimensions pertinent to spinal trauma. The newly developed universal disease-specific outcome instrument AO Spine Patient Reported Outcome Spine Trauma (AO Spine PROST) shows great promise at resolving this issue for spinal trauma research [45]. This tool includes both the patient's and healthcare professional's perspectives on the loss of functioning and limitations in daily living. It has been shown that, for patients with spinal column injury without complete paralysis, the loss of functioning and limitations in daily living is more important than pain [46]. The significant determinants for a worse AO Spine PROST score were a longer delay in returning to work or the inability to return to work [47]. Our present study shows that the dominance of surgical treatment from a socioeconomic perspective resides mostly in the productivity loss and caregiver loss, which supports the direction of outcome measurement in trauma towards measuring acute loss of functioning and limitations in daily living. Future studies on spinal trauma populations should consider using the AO Spine PROST tool and other measures of daily functioning.

This study provides valuable insight, but it must be interpreted in the context of its study design. The first major strength of this study is that data was obtained through a prospective international multicenter cohort study. This allows the results of the study to be valuable from a global perspective with its wide range of surgical management (from anterior and posterior reconstruction to percutaneous posterior fixation) and nonoperative management (from bracing to no bracing and bed rest to rapid mobilization). When considering the results from the study, policy makers wanting to shape their national policy should put results in context of their healthcare system. However, the methology applied for this analysis from a societal perspective remains applicable. Given the nonrandomized nature of the study, it is possible that selection bias affects our results. However, the study exploited the different schools of thoughts worldwide and global equipoise allowing for a "randomization" by region. This report is strengthened by the multiple timeframes analyzed, and sensitivity analyses conducted, to provide a complete overview of the different considerations for cost and utility of surgical TL burst fracture management. The use of patient diaries to obtain resource usage data relies on patient compliance and comprehensiveness in capturing this information. Societal factors such as productivity loss and caregiver requirements were large drivers in the model and were dependent on the completeness of patient diary data collection. At 2-year follow-up, the diary completion was excellent at 88% providing adequate data for meaningful results. Another limitation is the use of assumptive modeling to determine results beyond the timeframe of the study. For the working-lifetime horizon, assumptions are required to determine that costs and utilities will remain similar to what was seen in the first two years. The impact of this is minimized by the discounting of costs and utilities, while also considering plausible ranges of key factors for sensitivity analysis. These methods ensure the most rigorous assessment was conducted to answer the research question of this study.

Conclusion

Our cost-utility analysis showed surgical management to be dominant at 2 years compared to nonoperative management in neurologically intact TL burst fractures from a societal perspective. This finding was maintained through the working-lifetime horizon. Surgical treatment became cost-effective largely due to the greater productivity loss of patients and caregivers within the nonsurgical group. This investigation highlights the viability for surgical management of TL burst fractures to provide societal benefit especially when productivity is valued.

Declaration of Competing Interest

One or more of the authors declare financial or professional relationships on ICMJE-TSJ disclosure forms.

CRediT authorship contribution statement

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Supplementary materials

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References

[1] Aras EL, Bunger C, Hansen ES, Søgaard R. Cost-Effectiveness of Surgical Versus Conservative Treatment for Thoracolumbar Burst Fractures. Spine (Phila Pa 1976) 2016;41(4):337–43.
[2] Vaccaro AR, Oner C, Kepler CK, Dvorak M, Schnake K, Bellabarba C, et al. AOSpine thoracolumbar spine injury classification system: fracture description, neurological status, and key modifiers. Spine (Phila Pa 1976) 2013;38(23):2028–37.
[3] Dai LY, Jiang SD, Wang XY, Jiang LS. A review of the management of thoracolumbar burst fractures. Surg Neurol 2007;67(3):221–31. discussion 231.
[4] Ghobrial GM, Jallo J. Thoracolumbar spine trauma: review of the evidence. J Neurosurg Sci 2013;57(2):115–22.
[5] van der Roer N, de Bruyne MC, Bakker FC, van Tulder MW, Boers M. Direct medical costs of traumatic thoracolumbar spine fractures. Acta Orthop 2005;76(5):662–6.
[6] Yun BJ, Myriam Hunink MG, Prabhakar AM, Heng M, Liu SW, Qudsi R, et al. Diagnostic Imaging Strategies for Occult Hip Fractures: A Decision and Cost-Effectiveness Analysis. Acad Emerg Med 2016;23(10):1161–9.
[7] Rometsch E, Spruit M, Härtl R, McGuire RA, Gallo-Kopf BS, Kalampoki V, et al. Does Operative or Nonoperative Treatment Achieve Better Results in A3 and A4 Spinal Fractures Without Neurological Deficit?: Systematic Literature Review With Meta-Analysis. Global Spine Journal 2017;7(4):350–72.
[8] Gnanenthiran SR, Adie S, Harris IA. Nonoperative versus operative treatment for thoracolumbar burst fractures without neurologic deficit: a meta-analysis. Clin Orthop Relat Res 2012;470(2):567–77.
[9] Abudou M, Chen X, Kong X, Wu T. Surgical versus non-surgical treatment for thoracolumbar burst fractures without neurological deficit. Cochrane Database Syst Rev 2013(6):CD005079. Jun.
[10] Gm G, Cm M, M M, Rt D, Ar V, Mg F, et al. Operative and nonoperative adverse events in the management of traumatic fractures of the thoracolumbar spine: a systematic review. Neurosurgical focus 2014;37(1). [Internet][cited 2022 Jun 4]. Available from: https://pubmed.ncbi.nlm.nih.gov/24981907/.
[11] Polinder S, Meerding WJ, van Baar ME, Toet H, Mulder S, van Beeck EF, et al. Cost estimation of injury-related hospital admissions in 10 European countries. J Trauma 2005;59(6):1283–90. discussion 1290-1291.
[12] Chan BCF, Craven BC, Furlan JC. A scoping review on health economics in neurosurgery for acute spine trauma. Neurosurg Focus 2018;44(5):E15.
[13] Hitchon PW, Torner JC, Haddad SF, Follett KA. Management options in thoracolumbar burst fractures. Surg Neurol 1998;49(6):619–26. discussion 626-627.
[14] Wood K, Buttermann G, Butterman G, Mehbod A, Garvey T, Jhanjee R, et al. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. J Bone Joint Surg Am 2003;85(5):773–81.
[15] Shen WJ, Liu TJ, Shen YS. Nonoperative treatment versus posterior fixation for thoracolumbar junction burst fractures without neurologic deficit. Spine (Phila Pa 1976) 2001;26(9):1038–45.
[16] Weinstein MC, Siegel JE, Gold MR, Kamlet MS, Russell LB. Recommendations of the Panel on Cost-Effectiveness in Health and Medicine. JAMA 1996;276(15):1253–8.
[17] Shemilt I, James T, Marcello M. A web-based tool for adjusting costs to a specific target currency and price year. Evidence & Policy 2010;6(1):51–9.
[18] Djurasovic M, Gum JL, Crawford CH, Owens K, Brown M, Steele P, et al. Cost-effectiveness of minimally invasive midline lumbar interbody fusion versus traditional open transforaminal lumbar interbody fusion. J Neurosurg Spine 2019:1–5.
[19] Maillard N, Buffenoir-Billet K, Hamel O, Lefranc B, Sellal O, Surer N, et al. A cost-minimization analysis in minimally

invasive spine surgery using a national cost scale method. Int J Surg 2015;15:68–73.

[20] Zhong L, Mahmoudi E, Giladi AM, Shauver M, Chung KC, Waljee JF. Utilization of Post-Acute Care Following Distal Radius Fracture Among Medicare Beneficiaries. J Hand Surg Am 2015;40(12):2401–2409.e8.

[21] Durán I, Garzón C, Sánchez A, García-Carbonero I, Pérez-Gracia JL, Seguí-Palmer MÁ, et al. Cost analysis of skeletal-related events in Spanish patients with bone metastases from solid tumours. Clin Transl Oncol 2014;16(3):322–9.

[22] Dimai HP, Redlich K, Schneider H, Siebert U, Viernstein H, Mahlich J. [Direct and indirect costs of fractures due to osteoporosis in Austria]. Gesundheitswesen 2012;74(10):e90–8.

[23] Tannenbaum C, Diaby V, Singh D, Perreault S, Luc M, Vasiliadis HM. Sedative-hypnotic medicines and falls in community-dwelling older adults: a cost-effectiveness (decision-tree) analysis from a US Medicare perspective. Drugs Aging 2015;32(4):305–14.

[24] Barlow BT, McLawhorn AS, Westrich GH. The Cost-Effectiveness of Dual Mobility Implants for Primary Total Hip Arthroplasty: A Computer-Based Cost-Utility Model. J Bone Joint Surg Am 2017;99(9):768–77.

[25] Kanters TA, Bouwmans CAM, van der Linden N, Tan SS. Hakkaart-van Roijen L. Update of the Dutch manual for costing studies in health care. PLoS One 2017;12(11):e0187477.

[26] Borgström F, Ström O, Kleman M, McCloskey E, Johansson H, Odén A, et al. Cost-effectiveness of bazedoxifene incorporating the FRAX algorithm in a European perspective. Osteoporos Int 2011;22(3):955–65.

[27] Pergolotti M, Lavery J, Reeve BB, Dusetzina SB. Therapy Caps and Variation in Cost of Outpatient Occupational Therapy by Provider, Insurance Status, and Geographic Region. Am J Occup Ther 2018;72(2). 7202205050p1–9.

[28] Dimai HP, Redlich K, Peretz M, Borgström F, Siebert U, Mahlich J. Economic burden of osteoporotic fractures in Austria. Health Econ Rev 2012 Jun 27;2(1):12.

[29] Burgers PTPW, Hoogendoorn M, Van Woensel E aC, Poolman RW, Bhandari M, Patka P, et al. Total medical costs of treating femoral neck fracture patients with hemi- or total hip arthroplasty: a cost analysis of a multicenter prospective study. Osteoporos Int 2016;27(6):1999–2008.

[30] Wilke T, Tesch S, Scholz A, Kohlmann T, Greinacher A. The costs of heparin-induced thrombocytopenia: a patient-based cost of illness analysis. J Thromb Haemost 2009;7(5):766–73.

[31] Katz JN, Smith SR, Collins JE, Solomon DH, Jordan JM, Hunter DJ, et al. Cost-effectiveness of nonsteroidal anti-inflammatory drugs and opioids in the treatment of knee osteoarthritis in older patients with multiple comorbidities. Osteoarthritis Cartilage 2016;24(3):409–18.

[32] Al MJ, Maniadakis N, Grijseels EWM, Janssen M. Costs and effects of various analgesic treatments for patients with rheumatoid arthritis and osteoarthritis in the Netherlands. Value Health 2008;11(4):589–99.

[33] Vertuani S, Nilsson J, Borgman B, Buseghin G, Leonard C, Assietti R, et al. A Cost-Effectiveness Analysis of Minimally Invasive versus Open Surgery Techniques for Lumbar Spinal Fusion in Italy and the United Kingdom. Value Health 2015;18(6):810–6.

[34] Fowler RA, Sanders GD, Bravata DM, Nouri B, Gastwirth JM, Peterson D, et al. Cost-effectiveness of defending against bioterrorism: a comparison of vaccination and antibiotic prophylaxis against anthrax. Ann Intern Med 2005;142(8):601–10.

[35] Hübner C, Hübner NO, Muhr M, Claus F, Leesch H, Kramer A, et al. Cost analysis of hospitalized Clostridium difficile-associated diarrhea (CDAD). GMS Hyg Infect Control 2015;10:Doc13.

[36] Hanson G, Lyons KW, Fournier DA, Lollis SS, Martin ED, Rhynhart KK, et al. Reducing Radiation and Lowering Costs With a Standardized Care Pathway for Nonoperative Thoracolumbar Fractures. Global Spine J 2019;9(8):813–9.

[37] National Average Wage Index [Internet]. [cited 2024 Mar 19]. Available from: https://www.ssa.gov/oact/cola/AWI.html

[38] Arlandis-Guzman S, Errando-Smet C, Trocio J, Arumi D, Rejas J. Cost-effectiveness analysis of antimuscarinics in the treatment of patients with overactive bladder in Spain: a decision-tree model. BMC Urol 2011;11:9.

[39] Whitehead SJ, Ali S. Health outcomes in economic evaluation: the QALY and utilities. Br Med Bull 2010;96:5–21.

[40] Thoma A, Haines T, Veltri K, Goldsmith CH, O'Brien BJ, Quartly C. A methodological guide to performing a cost-utility study comparing surgical techniques. Can J Plast Surg 2004;12(4):179–87.

[41] Davis EN, Chung KC, Kotsis SV, Lau FH, Vijan S. A cost/utility analysis of open reduction and internal fixation versus cast immobilization for acute nondisplaced mid-waist scaphoid fractures. Plast Reconstr Surg 2006;117(4):1223–35. discussion 1236-1238.

[42] Neumann PJ, Cohen JT, Weinstein MC. Updating Cost-Effectiveness — The Curious Resilience of the $50,000-per-QALY Threshold. N Engl J Med 2014;371(9):796–7.

[43] Siebenga J, Segers MJ, Leferink VJ, Elzinga MJ, Bakker FC, Duis HJT, et al. Cost-effectiveness of the treatment of traumatic thoracolumbar spine fractures: Nonsurgical or surgical therapy? Indian J Orthop 2007;41(4):332–6.

[44] Copley PC, Tadross D, Salloum N, Woodfield J, Edlmann E, Poon M, et al. A systematic review identifying outcome measures used in evaluating adults sustaining cervical spine fractures. Eur Spine J 2022;31(12):3365–77.

[45] Sadiqi S, Lehr AM, Post MW, Dvorak MF, Kandziora F, Rajasekaran S, et al. Development of the AOSpine Patient Reported Outcome Spine Trauma (AOSpine PROST): a universal disease-specific outcome instrument for individuals with traumatic spinal column injury. Eur Spine J 2017;26(5):1550–7.

[46] Oner FC, Sadiqi S, Lehr AM, Aarabi B, Dunn RN, Dvorak MF, et al. Toward developing a specific outcome instrument for spine trauma: an empirical cross-sectional multicenter ICF-based study by AOSpine Knowledge Forum Trauma. Spine (Phila Pa 1976) 2015;40(17):1371–9.

[47] Buijs GS, de Gendt EEA, Sadiqi S, Post MW, Muijs SPJ, Oner FC. Long-Term Reliability and Validity of the AO Spine PROST (Patient-Reported Outcome Spine Trauma). Spine (Phila Pa 1976) 2022;47(17):E562–9.