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Authors' contribution: PD, GK, SF, and FCF designed the study. PD and ASF screened and selected clinical studies and extracted clinical study data. PD, JB, NA, HP, and GK created the decision tree, defined model assumptions, and cost items and quantities. PD developed the computational model with support from LF. PD and

FCF, analyzed the data. PD drafted the manuscript with input from LF and FCF. JB, NA, HP, GK, and SF revised the final manuscript. All authors read and approved the final manuscript.

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Early analysis shows that endoscopic flexor hallucis longus transfer has a promising cost-effectiveness profile in the treatment of acute Achilles tendon ruptures

Abstract

Purpose: Current options for treating an Achilles tendon rupture (ATR) include conservative and surgical approaches. Endoscopic flexor hallucis longus (FHL) transfer has been recently proposed to treat acute ruptures, but its cost-effectiveness potential remains to be evaluated. Therefore, the objective was to perform an early cost-effectiveness analysis of endoscopic FHL transfer for acute ATRs, comparing to costs and benefits of current treatments from a societal perspective.

Methods: A conceptual model was created, with a decision tree, to outline the main health events during the treatment of an acute ATR. The model was parameterized using secondary data. A systematic review of the literature was conducted to gather information on the outcomes of current treatments. Data related to outcomes of endoscopic FHL transfers in acute Achilles ruptures was obtained from a single prospective study. Analysis was limited to the two first years. The incremental cost-effectiveness ratio was the main outcome used to determine the preferred strategy. A willingness-to-pay threshold of $100,000 per Quality-adjusted Life-Year was used. Sensitivity analyses were performed to determine whether changes in input parameters would cause significant deviation from the reference case results. Specifically, a probability sensitivity analysis was conducted using Monte Carlo simulations, and a one-way sensitivity analysis was conducted by sequentially varying each model parameter within a given range.

Results: For the reference case, incremental cost-effectiveness ratios exceeded the willingness-to-pay threshold for all the surgical approaches. Overall, primary treatment was the main cost driver. Conservative treatment showed the highest direct costs related to the treatment of complications. In the probabilistic sensitivity analysis, at a willingness-to-pay threshold of $100,000, open surgery was cost-effective in 50.9%, minimally invasive surgery in 55.8%, and endoscopic FHL transfer in 72% of the iterations. The model was most sensitive to parameters related to treatment utilities, followed by the costs of primary treatments.

Conclusion: Surgical treatments have a moderate likelihood of being cost-effective at a willingness-to-pay threshold of $100,000, with endoscopic FHL transfer showing the highest likelihood. Following injury, interventions to improve health-related quality of life may be better suited for improved cost-effectiveness.

Level of Evidence: Level III.

Keywords: Achilles tendon ruptures; surgical treatment; economic and decision analysis; computer simulation model.

Introduction

Achilles tendon ruptures (ATRs) are common injuries, with an incidence of 10.8 to 30.2 per 100.000 person-years [10]. Current options include conservative and surgical approaches. However, there is no consensus on whether early functional rehabilitation or surgical treatment (with a similar rehabilitation protocol) provides superior outcomes [50].

Long-term deficits are common regardless of adequate treatment [40]. Time-series analyses of isokinetic strength assessments in patients with ATRs revealed impairments in plantarflexor strength and a reduced capacity to sustain high levels of plantarflexor moment in the injured limb [57]. These strength deficits may be related to tendon elongation or inferior mechanical properties [16]. It is also noteworthy that Achilles tendon (AT) degenerative changes often, but not always, precedes rupture [49].

Flexor hallucis longus (FHL) hypertrophy is commonly observed after ATRs [25]. In addition, previous research has shown that soleus muscle atrophy is correlated with FHL and other deep flexors hypertrophy [25]. Thus, transferring the FHL in the acute setting could help overcome deficiencies in plantarflexion strength and possibly compensate for the inferior mechanical properties of the ruptured AT by relocating the FHL tendon insertion to a more biomechanically advantageous site, i.e., near the insertion of the AT.

Endoscopic FHL transfer has been proposed as a treatment option for chronic, or failed, AT repairs [7, 22, 33] and acute complex ruptures [32]. Recently, Batista et al. published a prospective case series of patients with acute ATRs treated with endoscopic FHL transfers, with satisfactory results and minimal complications [6]. In this study, an isolated endoscopic FHL transfer was performed, regardless of rupture complexity or location.

Cost-effectiveness analysis (CEA) is a valuable tool to guide policymaking and help physicians, patients, and regulators make informed resource allocation decisions. Previous economic analyses regarding the treatment of acute ATRs have made comparisons between open surgery and conservative treatment [23, 27, 54, 55, 59], between open surgery, percutaneous surgery, functional treatment and immobilization [19], and between open and percutaneous surgery [11]. However, the cost-effectiveness potential of endoscopic FHL transfer remains to be evaluated. Early

CEA is used to assess the likelihood of an intervention being cost-effective in different prospective scenarios [20], which is particularly important when designing clinical trials or developing new techniques or devices. The main advantage of early CEAs is assessing potential cost savings while new technologies are still being developed or in the early stages of introduction, which may be used to guide investment, research, or healthcare decisions. As they are being implemented in the early stages of development, early CEAs frequently rely on expert opinions, observational studies, or small clinical trials to define model parameters.

The objective of this study was to perform an early CEA of endoscopic FHL transfer in the setting of a complete acute rupture of the AT. This analysis compared the costs and benefits of endoscopic FHL transfers for acute ATRs with conservative treatment, open surgery, and minimally invasive surgery (MIS) in the health care sector and societal perspectives.

Materials and Methods

This study was conducted according to the recommendations of the Second Panel on Cost-effectiveness in Health and Medicine [52].

Study context

This study's target population was patients aged 18 to 65 with acute ATRs. The following current treatments were considered: conservative treatment, open surgery, and MIS; complementary functional rehabilitation was assumed to be performed in all cases. The timeframe was two years. This study reports a reference case based on a societal perspective, meaning costs and health events are incorporated regardless of who pays and benefits [20]. Comparisons are made regarding incremental utilities, measured as Quality-Adjusted Life-Years (QALYs) and incremental costs.

Conceptual model

The conceptual model, created using a decision tree, aimed to outline the main possible health events during treatment of an acute ATR and the follow-up actions needed. The decision tree, shown in Figure 1, was made using the *web app* Lucidchart (Lucid Software Inc., South Jordan, Utah).

Patients were assumed to be treated in the acute setting without significant delays. Regardless of the treatment option selected, six main health events during/after treatment were considered: the patient recovered or had one of five complications. The five complications considered were: re-rupture; minor wound healing problems (WHPs) due to skin breakdown or superficial infection; major WHPs due to deep surgical infection and wound dehiscence, not amenable to conservative treatment; sural nerve injury; and deep venous thrombosis (DVT). These complications were chosen as main health events because their occurrence causes significant functional debilitation [58] or may require prolonged treatment. Patients suffering re-ruptures after the three current treatments were assumed to be treated with open revision surgery (ORS) as described by Nilsson-Helander et al. [41]. Re-ruptures after endoscopic FHL transfers were assumed to be treated conservatively [6]. Conservative treatment of re-ruptures after endoscopic FHL transfers was based on the assumption that the transferred tendon is not affected and on literature reports of treatment of chronic injuries or failed AT repairs using only this procedure with acceptable outcomes [7, 22, 33]. Previous studies of endoscopic FHL transfer for chronic ATRs treatment have not reported, to date, rupture of the transferred tendon [7, 22, 33, 56].

This conceptual model was developed into a Markov model, using MATLAB Release 2019a (The MathWorks, Inc., Natick, Massachusetts) to assess how a simulated cohort of 100,000 patients would be distributed. Complications were mutually exclusive and considered to occur in the first three months. Model assumptions regarding health events are shown in Table 1.

Reference case

The model was parameterized using secondary data obtained from an extensive literature review. In addition, a systematic review of the literature was conducted to gather information on complication rates of current ATR treatments (see supplemental material). Only therapeutic studies with Level of Evidence 1, according to the Oxford Centre for Evidence-Based Medicine Levels of Evidence Working Group [44], were included. When applicable, data from multiple sources were combined using weighted averages. One researcher performed data collection, and another researcher cross-checked the extracted data.

Probabilities: Transition probabilities of current treatments were defined based on the seven papers included in the systematic review [21, 29, 35, 37, 42, 46, 60]. The study search and selection flowchart can be seen in Figure S1 (supplemental material). Studies' demographic and outcome data can also be found in the supplemental material (Tables S1 and S2, respectively). Outcome data related to endoscopic FHL transfer was retrieved from the study by Batista et al. [6] (Table 3). Complication rates after ORS were retrieved from the study by Nilsson-Helander et al. [41]. Transition probabilities of current treatments, endoscopic FHL transfer, and ORS used for the reference case can be found in Table 2.

Utilities: QALYs is a measure of disease burden that combines the health-related quality of life (HRQoL) and life expectancy. This measure varies between 0 and 1, where 0 represents "equal to being dead" and 1 represents one year of life in the best possible health state. The range of values for QALYs employed in this study follows patient-reported outcome measures obtained from the literature [13, 45, 46, 59]. Accordingly, utilities for patients treated conservatively, without further complications, were assumed to be, for the first three months, 3 to 6 months, and 6 to

24 months after injury, respectively, 0.74, 0.85, and 0.89 [13, 45, 46, 59]. For patients treated surgically (open surgery, MIS and FHL transfer) these were assumed to be 0.75, 0.87, and 0.93 [13, 45, 46, 59]. Since no experimental data is available on the effect of complications on treatment utilities, QALYs were discounted throughout the study's two-year timeframe by 10% or 20% in case of minor (sural nerve injuries and DVTs) or major complications (re-ruptures and major WHPs), respectively, based on reports of the effect of complications on treatment outcomes [9, 34, 48]. The utilities in patients with minor WHPs were not discounted. The current analysis is limited to the first two years, so the current model assumes that all the recovered patients have the same QALY utility for the rest of their life following the 24 months after treatment.

Costs: Cost items were defined for each node in the decision tree and were identified, whenever appropriate, through Current Procedural Terminology (CPT) codes selected from the literature [55] (Table S3, supplemental material). Quantities per cost item were defined based on previously published reports and this study's research team's clinical experience (Table S4, supplemental material) [3, 4, 8, 9, 11, 12, 15, 17, 23, 26, 28, 30, 31, 38, 39, 41, 47, 51, 53, 55, 59]. These quantities were explicitly defined for each node/item pair. Average prices of diagnostic and therapeutic procedures for the Boston, Massachusetts, area were extracted, during June 2021, from information publicly available on the FAIR Health Consumer website [18]. No specific cost value was found for the endoscopic FHL transfer; thus, the same procedure price for primary repairs was used in the reference case. The drug price ranges included in the model were extracted from the *Medicare Part D Drug Spending and Utilization* database [36]. Unitary prices for each cost item can be found in the supplemental material (Table S5).

Costs related to time off work were calculated using the human capital method. This method focuses on the patient's perspective and productivity lost due to illness or injury. Productivity costs are calculated as the product of total hours lost and the hourly wage [20]. It was assumed that a healthy person works 42 hours per week, with a mean hourly wage of $27 (U.S. national average in 2019) [43], considering a societal perspective in an American setting. Time until return-to-work (RTW) after open and MIS surgical treatments were the same, as evidence suggests that open and MIS repairs provide similar outcomes [1]. Since specific values for patients subjected to endoscopic FHL transfers are currently unavailable, the same time until RTW for open and MIS surgeries was adopted. Time until RTW after revision surgery was considered to vary similarly to primary treatments because a specific average time until RTW could not be found. In the study by Nilsson-Helander et al., patients with sedentary occupations could RTW within one week of surgery, and 96.4% of patients could return to their activities within six months of the revision surgery [41], which is similar to what was considered for primary surgeries. Data regarding the time until RTW for each specific complication can be found in the supplemental material file (Table S4).

Costs were estimated in 2019 U.S. dollars at constant values. No capital discounting or inflation adjustment was applied, given the short duration of the study. The total cost of each treatment was computed using the following method: for each node, the cost items' costs were summed after multiplying each unitary cost by the assigned quantity; for each patient in the virtual cohort, the costs of the nodes representing the several treatments to which the patient was submitted were aggregated; and finally, the costs associated to the several patients of the virtual cohort were summed. The values used in the reference case model are summarized in Table S6 (supplemental material) under "Reference case."

Cost-effectiveness analysis

The main outcome used to determine the preferred strategy was the incremental cost-effectiveness ratio (ICER), defined as the ratio of differences between two treatments regarding utilities and costs. The ICER is calculated as:

$$ICER = \frac{Cost_{Treatment} - Cost_{Control}}{QALY_{Treatment} - QALY_{Control}}$$

where *Control* is the treatment with the lowest average total cost. The ICER represents the cost of one added QALY. For this study, a willingness-to-pay (WTP) threshold ICER of $100,000 per QALY was adopted, which is between one and two times the Gross Domestic Product per capita, as recommended by the World Health Organization for cost-effectiveness studies of health-related interventions in developed countries [14].

Other model outputs considered are average QALYs in the cohort, direct and indirect costs, and the net monetary benefit (NMB). The NMB is calculated as:

$$NMB = (Benefits * \lambda) - Costs$$

where λ is the WTP threshold. The incremental NMBs (ΔNMB) are calculated as the NMB for each surgical treatment less the NMB for the conservative treatment used as control.

Sensitivity analyses

Sensitivity analyses were performed to determine whether changes in input parameters would cause significant deviation from the reference case results.

Probabilistic sensitivity analysis

A probabilistic sensitivity analysis (PSA) was conducted to account for variation in model parameters around a central value and confirm model robustness. Therefore, Monte Carlo simulations were used to observe how the model responded to randomly generated multiple input variables for an *n* number of iterations. Model input parameters were randomly sampled for each iteration from probabilistic distributions derived from data found in the literature or the research team's clinical experience. The number of iterations was determined using the methodology proposed by Hatswell et al. [24]. The ΔNMBs were computed for each of the surgical treatments in each iteration. After each iteration, the 95% confidence interval (CI) for the ΔNMB of each surgical treatment was computed. A minimum of 1000 iterations were performed. The number of iterations was then progressively increased until CIs did not include zero. Random data sets were generated from probability distributions and fed into the model in each iteration. Beta distributions were used for complications rates, truncated normal distributions for utility metrics and hourly wages, and log-normal distributions for cost data. The cost-effectiveness acceptability curves for the surgical treatments were computed, estimating the probability of cost-effectiveness at different WTP thresholds.

One-way sensitivity analysis

A one-way sensitivity analysis was conducted by sequentially varying each model parameter within a given range, defined from the literature search, the research team's clinical experience, or a 25% variation from the reference case value. Model parameters used in the reference case and one-way sensitivity analysis can be found in Table S5 (supplemental material). The model was considered sensitive to a given parameter if: ICER varied more than $2000; ICER shifted from a value above to a value below the WTP threshold; or treatment rankings regarding ICERs, utilities, or costs were reordered. Model sensitivity to a parameter was calculated, per treatment, as the percentage change in the ICER from the reference case and presented as the average across the input value range. Values presented as outputs of this analysis are the model sensitivity to a given parameter and the threshold value of such parameter at which the ICER is below the WTP threshold (if applicable).

Results

In the reference case, ICERs exceeded the WTP threshold for all the surgical approaches, using the conservative case as control. Results of the reference case analysis can be found in Table 4.

Primary treatment was the main cost driver for all the treatments, although costs with complications can represent as much as 10.1% in patients treated conservatively (Table S7, supplemental material). Conservative treatment also showed the most considerable cumulative costs and losses in QALYs due to complications (Figure 2).

Probabilistic sensitivity analysis

A cost-effectiveness acceptability curve showing the probability of being cost-effective for the different WTP thresholds can be found in Figure 3. Convergence was obtained after 1,000 iterations (Figure S2, supplemental material). At a WTP threshold of $100,000, open surgery was cost-effective in 50.9%, MIS in 55.8%, and endoscopic FHL transfer in 72% of the iterations. The calculated costs for the reference case and PSA are comparable, both for primary treatment and for complications and their treatments (Figure S3, supplemental material). Open surgery was ranked the least cost-effective option in the PSA. Relative to other treatments, costs related to the treatment of complications and absence from work raised more in open surgery than in other treatments compared with the reference case.

One-way sensitivity analysis

The model was most sensitive to treatment utilities (QALYs, above 200% sensitivity) parameters, followed by the costs of primary treatment procedures (Figure

4). The specific minimal values for each parameter that made the ICER of a treatment sit below the WTP threshold are reported as threshold values and are shown in Table 6. Additional data regarding the results of the one-way sensitivity analysis can be found in the supplemental material file (Table S7).

Discussion

The most important finding of this early CEA was that an endoscopic FHL transfer showed the highest likelihood among surgical techniques of being a cost-effective treatment in the setting of an acute ATR.

Previous economic analyses comparing surgery with conservative treatment have mostly reported that conservative treatment is a more cost-effective option [19, 23, 27, 54, 55] or that cost-effectiveness of surgical treatment is weakly supported [59]. These studies employed different conceptual frameworks, and only three reported WTP thresholds. In the study by Koltsov et al. [27], conservative treatment was the cost-effective option in 71.7% and 69.1% of the simulations at \$50,000/QALY and \$100,000/QALY WTP thresholds, respectively. In the study by Westin et al. [59], likelihood of surgery being cost-effective was 57%, 69%, and 73%, respectively, at WTP thresholds of €50,000, €80,000, and €100,000 per QALY. Minimally invasive surgery was cost-effective at a threshold of \$100,000 in the study by Faucett et al. [19].

The critical difference in the abovementioned studies is the different HRQoL benefits attributed to conservative and surgical approaches. While Westin et al. [59] and Faucett et al. [19] assumed that surgery provided superior outcomes regarding QALYs, Koltsov et al. assumed that both treatments provided similar benefits [27], citing two randomized controlled trials as data sources [13, 46]. However, in one of the studies, while no statistical analyses directly comparing conservative and surgical treatments were performed, the HRQoL outcomes estimated were numerically different; with a median and an interquartile range, respectively, of 0.85 and 0.70 to 1.0 for the patients treated conservatively and 1.0 and 0.9 to 1.0 for the surgically treated patients [13]. Given the considerable model sensitivity to treatment benefits, it seems correct to attribute different treatment benefits even if these differences are small or without statistical significance.

The current study allocated the same benefits to endoscopic FHL transfer patients as other surgical treatments. However, prospectively collected data support the assumption that this treatment will provide at least similar benefits to the other surgical treatments [1, 6]. For example, the Achilles Tendon Total Rupture Score (ATRS) was higher, at a value of 95 ± 4.26, for endoscopic FHL transfer in the study by Batista et al. [6] than the values reported for open surgery by Olsson et al. [46], with ATRS value of 82 ± 20 and EQ-5D values of 0.91 ± 0.17. Therefore, future studies evaluating the HRQoL in patients subjected to endoscopic FHL transfers are of interest, especially considering that even a slight increase in QALYs after six months of surgery would render this treatment cost-effective. The same limitation applies to MIS, as benefits were assumed to equal those from open surgery. Regardless, current evidence supports the assumption of comparable patient-reported outcomes between these treatments, specifically between open and MIS [2] and between MIS and endoscopic FHL transfers [1].

The model herein assumes that patients treated in the acute setting with an endoscopic FHL transfer will not need revision surgery after re-rupture, which is supported by patient data [6]. Furthermore, studies have reported treating chronic injuries, or failed, AT repairs using only an endoscopic FHL transfer, with acceptable outcomes [7, 22, 33]. Regardless, one-way sensitivity analysis did not find this factor to be determinant, and thus this assumption may not significantly influence the outcomes of this study, possibly due to a relatively low number of re-ruptures in these patients. More studies are needed to evaluate the incidence and consequences of re-ruptures in this specific context.

A specific cost for endoscopic FHL transfer was not obtained because a CPT code for this procedure could not be identified. However, the direct cost of this procedure can be speculated to approximate that of an AT repair. Considering that the purpose of this study was to perform an early CEA, using the same direct costs of AT repairs as a starting point seemed a reasonable approach.

In the PSA, open surgery was the most expensive surgical treatment, despite having a lower ICER than MIS on the reference case. Accordingly, previous CEAs comparing open and MIS have deemed the latter more cost-effective [11, 19]. This difference in the cost-effectiveness ranking is due to subsequential costs of open surgery, which may be related to the treatment of complications. For example, albeit infrequent [8], complications such as major WHPs may require multiple surgeries or prolonged treatment [9] and significant time off work. Unfortunately, data related to the societal burden of complications related to ATRs is currently lacking, and certain approximations must be made. One key example is the duration of the sick leave after ORS. Here, it was considered that this parameter would vary similarly to primary surgeries, as it is stated in the referenced paper that patients with sedentary occupations were able to return to work one week after surgery, and 96.4% were able to RTW within six months, a time interval that is similar to that of primary surgeries without re-ruptures. However, even though the time range is similar, there is no guarantee that the probability distribution of time until RTW is similar between the two groups. Therefore, future research is needed to evaluate the costs and the utilities of complications related to ATRs.

Time until RTW after ATRs varies considerably in the literature [3, 4, 12, 15, 26, 28, 30, 38, 59]. In this study, an extensive literature search was performed to gather data regarding RTW after ATRs. Despite having the lowest upfront costs related to time off work, conservative treatment had the highest indirect costs, showing the complications' deleterious effect on a treatment's cost-effectiveness profile. Due to a lack of studies describing RTW for patients subjected to endoscopic FHL transfers, a similar time until RTW as in other surgical patients was assumed. In the study by Batista et al. [6], all patients returned to their previous activities within four months of treatment, which is comparable to those reported in other studies for MIS techniques [26, 30]. Future studies are needed to assess the time until RTW in patients treated with this approach for acute ATRs.

The main limitation of this study is the paucity of available data regarding endoscopic FHL transfers for treating ATRs in the acute setting. The early CEA model herein presented is based on a single prospective case series, and several modeling assumptions regarding the similarity between this approach and other surgical techniques had to be made. The results of the present study need to be considered in light of this limitation. Notwithstanding,. even if this study's results may be, at best, considered preliminary, the framework developed herein may be helpful for future investigations.

The relatively short time horizon is also a limitation of this study. It should be noted that some complications, namely re-ruptures, may cause long-term deficits and decrease overall treatment benefits [58]. Therefore, it is possible that extending the model's time frame would cause surgical treatments to be cost-effective since patients submitted to these treatments showed higher overall health benefits due to a lower probability of re-ruptures than patients treated conservatively.

Finally, another limitation of this study is the lack of other non-healthcare sector costs in the model, such as those related to hiring replacements for workers on sick leave. Thus, it could be argued that adding these to the indirect costs of treatments could change outcomes since threshold analysis showed that a relatively small increase in the indirect costs of conservative treatment would change the cost-effectiveness ranking.

Clinical and research significance

Although several limitations can be recognized, as is inherent to early CEAs, some considerations can be made with clinical and research implications.

First, sensitivity analyses revealed that endoscopic FHL transfer has the highest likelihood among surgical approaches of being cost-effective. Given the current controversy between surgical repair and conservative treatment of ATRs, a different approach, with a promising cost-effectiveness profile, can be worth considering. Second, this study uncovers several research opportunities. For example, information on the HRQoL outcomes of MIS repairs and endoscopic FHL transfers is currently lacking.

Conclusion

Surgical treatments have a moderate likelihood of being cost-effective at a WTP threshold of $100,000, with endoscopic FHL transfer showing the highest likelihood. Interventions to improve HRQoL may be better suited for enhanced cost-effectiveness.

List of Abbreviations

AT: Achilles tendon

ATR: Achilles tendon rupture

ATRS: Achilles Tendon Total Rupture Score

CEA: Cost-effectiveness analysis

CI: Confidence interval

DVT: Deep venous thrombosis

FHL: Flexor hallucis longus

HRQoL: Health-related quality of life

ICER: Incremental cost-effectiveness ratio

MIS: Minimally invasive surgery

NMB: Net monetary benefit

ORS: Open revision surgery

PSA: Probabilistic sensitivity analysis

QALYs: Quality-Adjusted Life-Years

RTW: Return-to-work

WHPs: Wound healing problems

WTP: Willingness-to-pay

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Tables

Table 1: Assumptions regarding treatments and health events

Node	Assumptions
Treatment	Surgical treatments are assumed to produce similar utilities and costs regarding office visits, physical therapy, and sick leave.
Complications	Utilities are discounted by 10% or 20% in case o minor or major complications.
Re-ruptures	The time from primary treatment to re-rupture is similar between treatments. The number of office visits and physical therapy sessions is similar to primary treatments. Sick leave after re-rupture is similar to primary treatments.
Minor WHP	These complications do not have a lasting effect on outcomes.
Major WHP	Patients with major wound healing complications have significant decreases in outcomes.
Sural nerve injury	Patients with sural nerve injuries return to work simultaneously as those without these injuries [34].
DVT	No statistically significant differences exist regarding rates of return to work and treatment outcomes between patients with and without DVT [5].

DVT: deep venous thrombosis. WHP: wound healing problems.

Table 2: Transition probabilities used in the reference case and one-way sensitivity analysis

Treatment	Uneventful recovery	Re-rupture	Minor WHP	Major WHP	Sural nerve injuries	DVT
CT[21, 29, 35, 37, 42, 46, 60]	86.5%	10.2%	1.0%	0.0%	1.3%	1.0 %
OS[21, 29, 35, 37, 42, 46, 60]	82.0%	2.3%	10.0%	0.7%	4.0%	1.0 %
MIS[21, 35]	83.0%	2.4%	7.3%	0.0%	4.9%	2.4 %
FHL[6]	92.8%	1.8%	3.6%	0.0%	0.0%	1.8 %
ORS[41]	71.5%	0.0%	10.7%	3.6%	7.1%	7.1 %

Transition probabilities were calculated using weighted means from the referenced studies for each outcome. CT: conservative treatment. DVT: deep venous thrombosis. FHL: endoscopic flexor hallucis longus transfer. MIS: minimally invasive surgery. OS: open surgery. ORS: open revision surgery. WHP: wound healing problem

Table 3: Patient (N = 56) demographics and outcomes from the study by Batista et al. 2020

Parameter	Value
Patient demographics	
Side	
Right	24 (42.9)
Left	32 (57.1)
Risk factors	
None	38 (67.9)
Anticholesterol drugs	9 (16.1)
Hypertension	3 (5.4)
Overweight	2 (3.6)
Smoker	4 (7.1)
Achilles tendon rupture site	
Insertional	5 (8.9)
Proximal	21 (37.5)
Middle	18 (32.1)
Distal	12 (21.4)
Age (years)	
Mean ± SD	36.4 ± 8.1
Median (range)	35.5 (25.0 to 59.0)
Follow-up (months)	
Mean ± SD	27.5 ± 7.3
Median (range)	27.0 (18.0 to 43.0)
Outcomes at 18 months	
AOFAS	
Median ± SD	95.4 ± 4.9
ATRS	
Median ± SD	95.2 ± 4.4
VAS	
Median ± SD	0.6 ± 0.9

Values are represented as numbers (%) except where specified otherwise. AOFAS: American Orthopaedic Foot & Ankle Society ankle-hindfoot score. ATRS: Achilles tendon total rupture score. SD: standard deviation. VAS: Visual analog pain scale.

Table 4: Results of the reference case analysis

Treatment	QALYs	Costs		NMB[#]	ICER[*]
		Direct	Indirect		
Conservative	0.83 (0.53 to 0.87)	$9,736 ($8,605 to $26,721)	$1,609 ($1,343 to $6,272)	$71,656 ($20,057 to $76,678)	-
Open surgery	0.89 (0.53 to 0.90)	$16,940 ($16,458 to $34,574)	$1,564 ($1,448 to $6,377)	$70,057 ($11,548 to $72,094)	$128,766
MIS	0.88 (0.53 to 0.90)	$17,732 ($17,258 to $35,374)	$1,538 ($1,448 to $6,377)	$69,172 ($10,748 to $71,294)	$145,653
Endoscopic FHL transfer	0.89 (0.53 to 0.90)	$16,747 ($16,543 to $25,412)	$1,506 ($1,448 to $4,272)	$70,909 ($23,203 to $72,008)	$112,122

[#]: cost-effectiveness threshold of $100,000. [*]: calculated using conservative treatment as control treatment. ICER: incremental cost-effectiveness ratio, defined as the cost of one additional QALY for the reference case cohort. FHL: flexor hallucis longus. MIS: minimally invasive surgery. NMB: net monetary benefit. QALYs: quality-adjusted life-years. Values are represented as mean per patient and range, except otherwise specified.

Table 6: Results of threshold analyses

	Reference case	Open surgery	Minimally invasive surgery	Endoscopic FHL transfer
Conservative treatment, established patient office visits	$3,405	$5,076	$5,965	$4,187
Surgical treatments, established patient office visits	$1,437	N/A	N/A	$629
Conservative treatment, cost of rehabilitation	$1,5678	$3,216	$4,077	$2,356
Surgical treatments, cost of rehabilitation	$1,113	N/A	N/A	$291
Surgery A	$9,341	$7,708	N/A	N/A
Surgery B	$9,341	N/A	N/A	$8,593
Conservative treatment, sick leave	$1,343	$2,995	$3,878	$2,112
Surgical procedures, sick leave	$1,448	N/A	N/A	$676
Conservative treatment, QALYs first 3 months after injury	0.74	0.67	0.63	0.71
Conservative treatment, QALYs 3 to 6 months after injury	0.85	0.72	0.64	0.79
Conservative treatment, QALYs 6 to 24 months after injury	0.89	0.86	0.85	0.88
Surgical treatment, QALYs 3 to 6 months after injury	0.87	1.00	N/A	0.93
Surgical treatment, QALYs 6 to 24 months after injury	0.93	0.95	0.97	0.94

Caption: Results of threshold analyses regarding parameters in which variation within the predefined range caused the increased cost-effectiveness ratio of a treatment to sit below the $100,000 willingness-to-pay threshold. Surgery A: primary Achilles tendon repair. Surgery B: endoscopic FHL transfer. FHL: flexor hallucis longus. N/A: not applicable. QALYs: quality-adjusted life-years.

Figures

Figure 1

Caption: Schematic representation of the decision tree. Nodes are represented by squares, circles, or triangles indicating a decision, uncertain event, or endpoint. Branches, represented by lines between or after a node, indicate clinical or health events. The health events after "revision open surgery" are the same after primary treatments. *: Re-ruptures after endoscopic flexor hallucis longus transfers are assumed to be treated conservatively. DVT: deep venous thrombosis. FHL: endoscopic flexor hallucis longus transfer. MIS: minimally invasive surgery. ORS: open revision surgery.

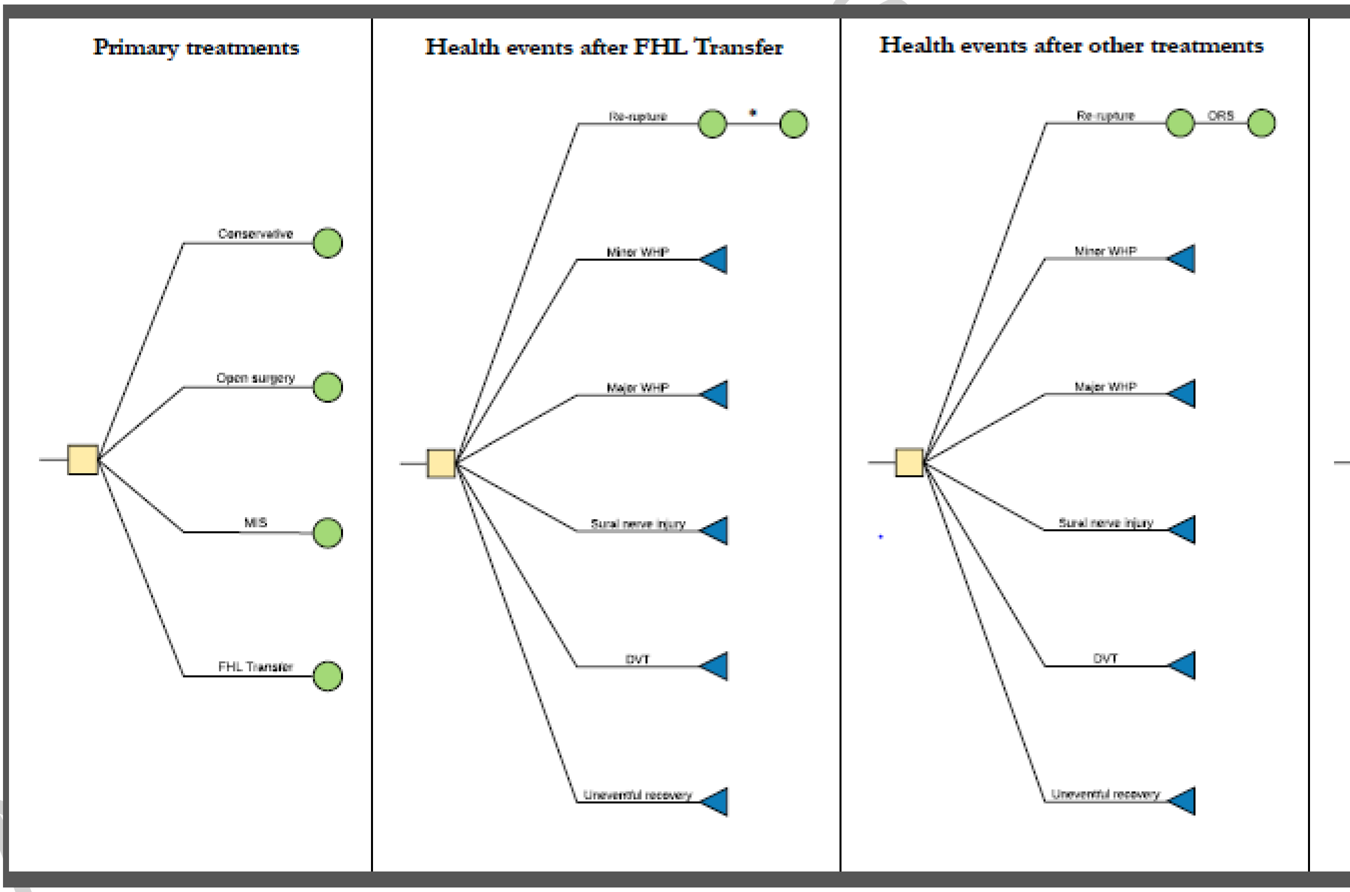


Figure 2

Caption: Cumulative costs and losses in quality-adjusted life-years due to complications in the cohort of the reference case. The bubble size is directly proportional to the number of patients with complications. FHL: endoscopic flexor hallucis longus transfer. MIS: minimally invasive surgery. QALY: quality-adjusted life-years.

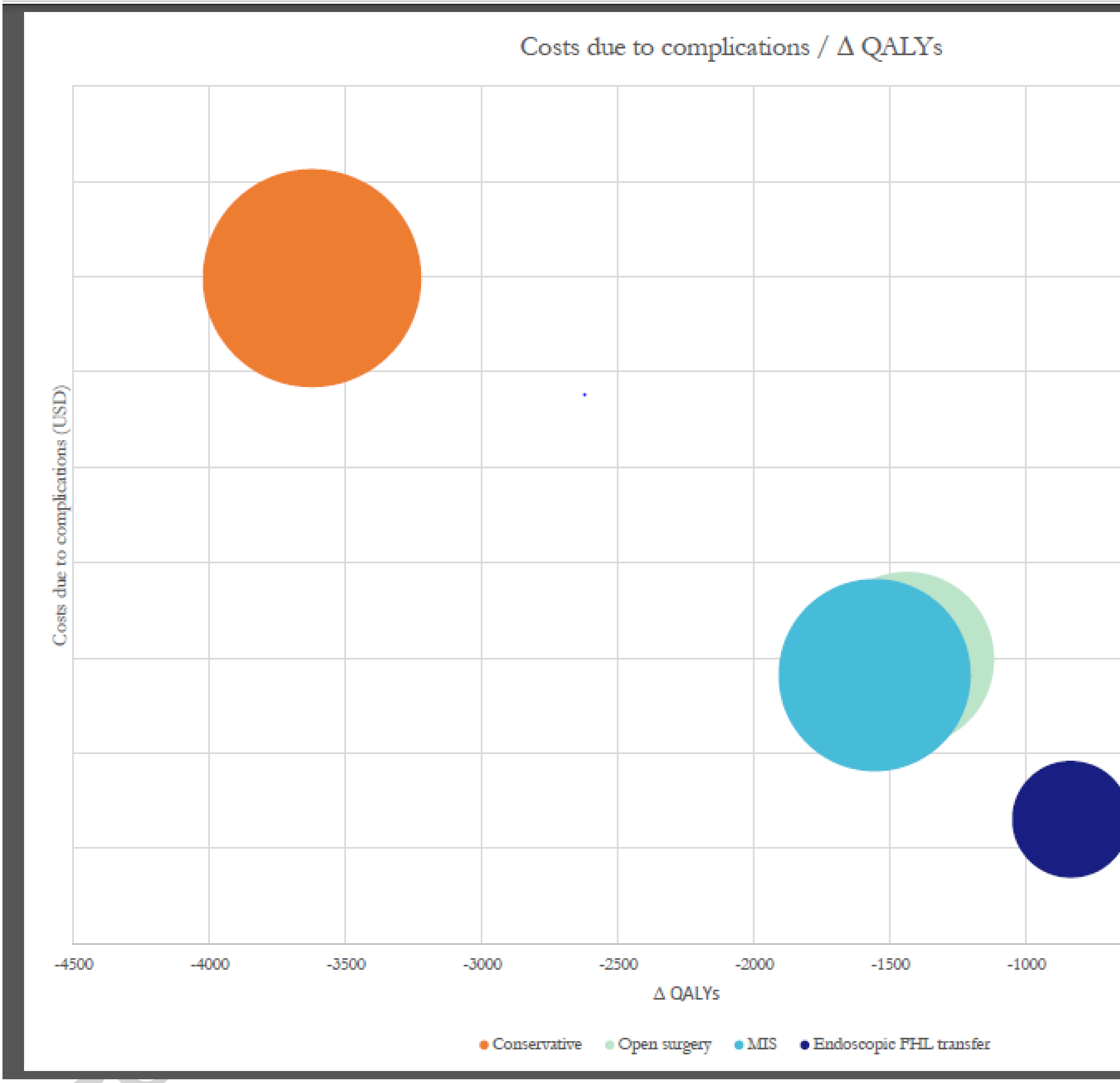


Figure 3
Caption: Cost-effectiveness acceptability curve for surgical treatments. Probability of cost-effectiveness vs. willingness-to-pay (WTP). Vertical lines represent WTP thresholds. QALY: quality-adjusted life-years.

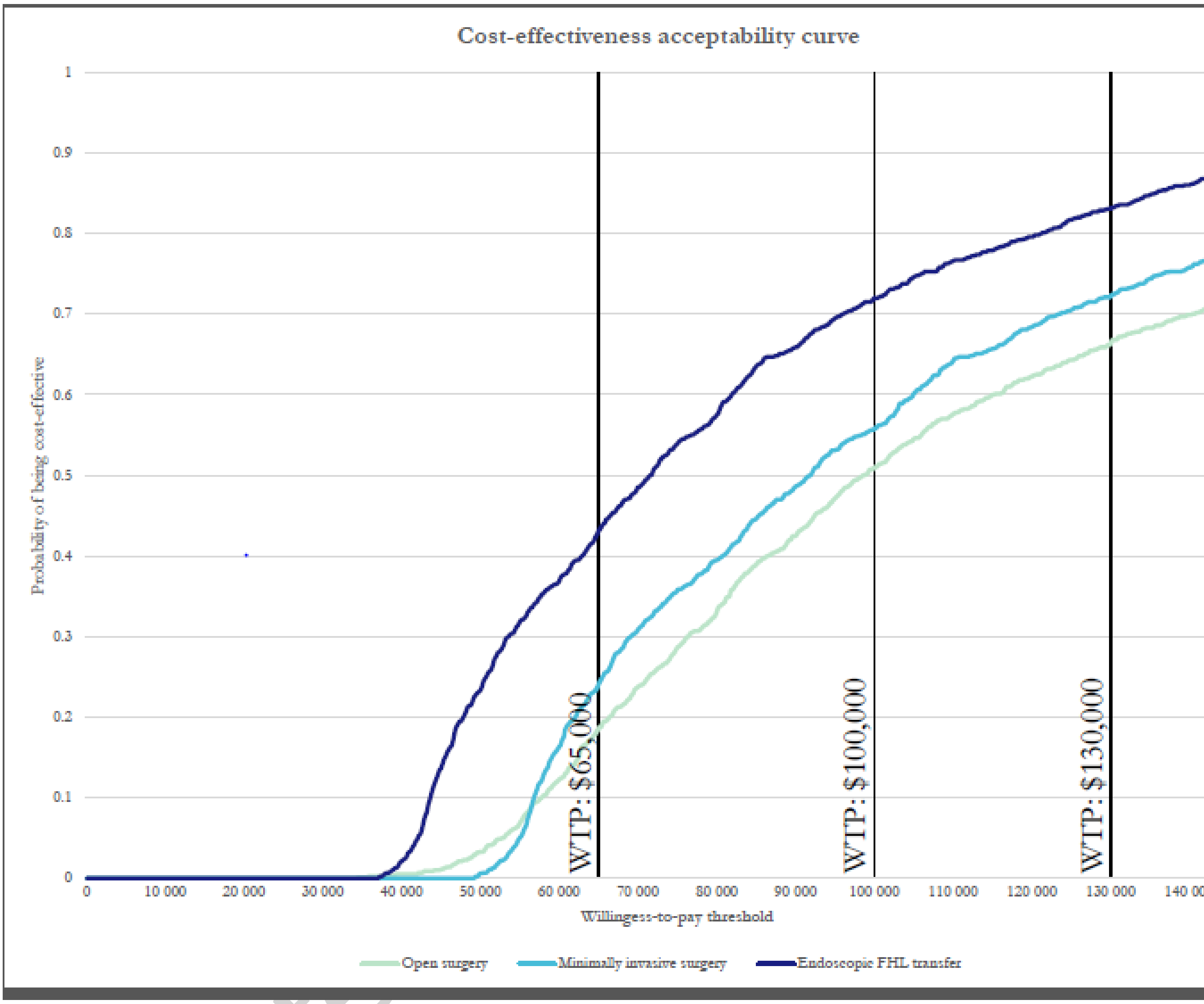
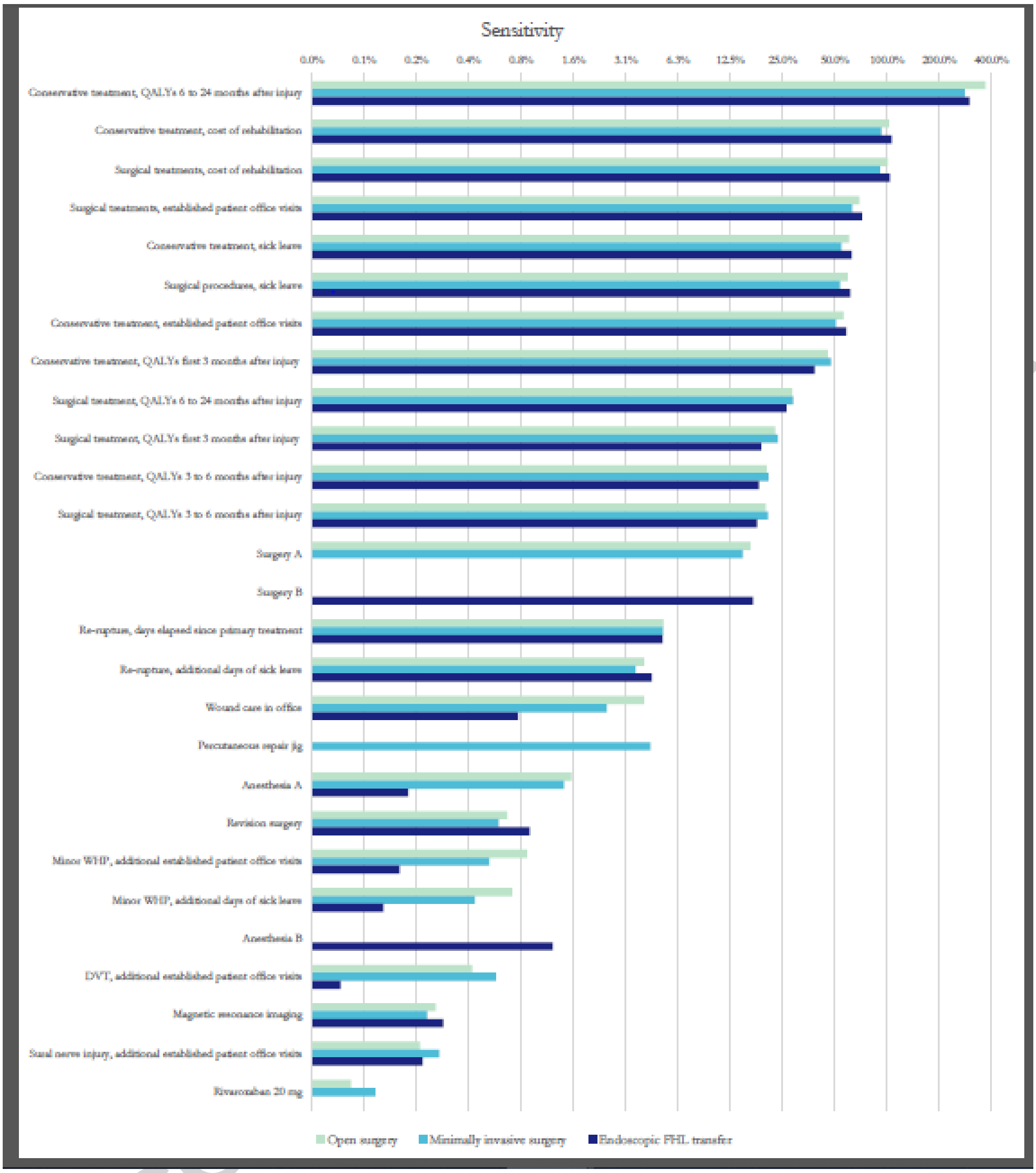


Figure 4

Caption: Results of one-way sensitivity analysis. Sensitivity was calculated as the percentage change in the ICER in relation to reference case values and presented as the average across the input value range for each treatment. Values are on a base two logarithmic scale. The absence of data signifies a lack of model sensitivity for that parameter/treatment pair. DVT: deep venous thrombosis. FHL: flexor hallucis longus. QALYs: quality-adjusted life-years. WHP: wound healing problems.


Sensitivity
0.0%
0.1%
0.2%
0.4%
0.8%
1.6%
3.1%
6.3%
12.5%
25.0%
50.0%
100.0%
200.0%
400.0%
Conservative treatment, QALYs 6 to 24 months after injury
Conservative treatment, cost of rehabilitation
Surgical treatments, cost of rehabilitation
Surgical treatments, established patient office visits
Conservative treatment, sick leave
Surgical procedures, sick leave
Conservative treatment, established patient office visits
Conservative treatment, QALYs first 3 months after injury
Surgical treatment, QALYs 6 to 24 months after injury
Surgical treatment, QALYs first 3 months after injury
Conservative treatment, QALYs 3 to 6 months after injury
Surgical treatment, QALYs 3 to 6 months after injury
Surgery A
Surgery B
Re-rupture, days elapsed since primary treatment
Re-rupture, additional days of sick leave
Wound care in office
Percutaneous repair jig
Anesthesia A
Revision surgery
Minor WHP, additional established patient office visits
Minor WHP, additional days of sick leave
Anesthesia B
DVT, additional established patient office visits
Magnetic resonance imaging
Sural nerve injury, additional established patient office visits
Rivaroxaban 20 mg
Open surgery
Minimally invasive surgery
Endoscopic FHL transfer