Article

AMERICAN ORTHOPAEDIC FOOT & ANKLE SOCIETY

Foot & Ankle Orthopaedics
2025, Vol. 10(2) 1–7
© The Author(s) 2025
DOI: 10.1177/24730114251332941
journals.sagepub.com/home/fao

# Study of Surgical Costs Associated With Tibiotalar Fusion

**Kade Wagers, MK[1], Chong Zhang, MS[2], Angela Presson, PhD[2], and Devon Nixon, MD[1]**

## Abstract

**Background:** There is growing focus on surgical costs related to common orthopaedic procedures. In this investigation, we studied surgical costs associated with tibiotalar arthrodesis.

**Methods:** Patients were retrospectively identified who had undergone primary fusion of the tibiotalar joint based on *Current Procedural Terminology* (*CPT*) codes from 2014 to 2020. Using the Value Driven Outcome (VDO) tool, we conducted an evaluation of both total direct costs and facility-related expenses. The VDO tool encompasses a comprehensive item-level database capable of capturing detailed cost information, which is subsequently presented as relative mean data. Adjustments were made to cost variables to reflect 2022 US dollars, and comparative multivariable analysis of costs in relation to treatment groups adjusting for demographic variables was performed using generalized linear models to yield cost ratios along with 95% CIs.

**Results:** Our cohort consisted of 262 patients who underwent primary ankle fusion procedures done by one of 4 fellowship-trained orthopaedic foot and ankle surgeons. There were no differences in demographic data or total operating room (OR) time based on surgical construct (screws-alone n = 228 vs anterior plate-screws n = 34). Total direct costs for anterior plate-screw constructs were 78% higher than screws alone (ratio in cost = 1.78, 95% CI 1.55-2.08, $P < .001$), adjusting for other variables. For all fusion constructs, every 1-hour increase in total OR time increased total direct costs by 29% (ratio in cost = 1.29, 95% CI 1.18-1.40, $P < .001$).

**Conclusion:** Enhancing cost-effectiveness of orthopaedic care remains an important objective. Our investigation found that anterior plate-screw constructs for tibiotalar arthrodesis have notably higher total costs compared with screw-only constructs. Many variables are considered when selecting surgical constructs for ankle arthrodesis. When clinically appropriate, screw-only ankle arthrodesis constructs could be considered if there is a need to reduce costs.

**Level of Evidence:** Level III, retrospective comparative study.

**Keywords:** surgical costs, ankle fusion

## Introduction

Arthrodesis of the tibiotalar joint (ankle fusion) is an established and common procedure for the treatment of ankle arthritis[2,4,6,30] with more than 80 000 surgeries performed between 2000 and 2010 in the United States alone.[26] Ankle fusions, when successful, can provide notable pain relief and improved mobility.[32,33]

There are various surgical techniques for ankle fusion surgeries.[2,3,9,23] However, there is no consensus on the optimal technique,[18,19,21,29] and decision making for surgical technique is influenced by patient and surgeon-specific factors. Data suggest that screws alone or anterior plating can both achieve similar union rates[17,24,27,31,35] and comparable hardware removal rates.[17,34] However, there have been

[1]Department of Orthopedic Surgery, University of Utah, Salt Lake City, UT, USA
[2]Division of Epidemiology, Department of Internal Medicine, University of Utah, Salt Lake City, UT, USA

**Corresponding Author:**
Devon Nixon, MD, Department of Orthopaedics, University of Utah, 590 Wakara Way, Salt Lake City, UT 84108, USA.
Email: devon.nixon@hsc.utah.edu

no studies examining the differences in surgical costs based on surgical fixation for ankle fusion.[5,28] In this study, we aimed to evaluate the factors that influence surgical costs for ankle fusion procedures. We hypothesized that cost would be greater for anterior plating because of the increased costs of the implants.

## Methods

### Data

We identified patients who had undergone primary fusion of the tibiotalar joint based on *Current Procedural Terminology* (*CPT*) codes (27870 and 29899) from 2014 to 2020. Exclusion criteria included patients with external fixator applications, use of tibiotalocalaneal nailing, or revision fusions. We considered all adult patients for inclusion (older than 18 years at the time of surgery). We characterized ankle fusion surgical constructs as either those involving screws alone or with the use of a precontoured, anteriorly based fusion plate. Total operating room (OR) time was determined from the electronic records and calculated when the patient entered and exited the OR (and not just surgical time alone).

Using the Value Driven Outcome (VDO) tool implemented at our institution, we conducted an evaluation of both total direct costs and facility-related expenses. Briefly, the VDO metric from our institution was first detailed in *JAMA* in 2016 and has been studied extensively since both within and outside orthopaedic surgery.[20] The VDO tool encompasses a comprehensive item-level database capable of capturing detailed cost information that allocates care costs to individual patient encounters, which is subsequently presented as relative mean data.[14] Direct costs are those incurred from direct patient care and grouped by imaging, supply, implant, pharmacy, laboratory, and facility use costs. Total direct costs are the sum total of these groupings. Facility use costs include space, equipment, and labor costs generated from each unit where patients were seen (excluding professional billing). The VDO tool has been used for more than a decade as a framework for understanding and improving health care costs and outcomes and has been used in other areas of orthopaedics at our institution.[14-16,20] Although this tool is unique to our University, the methodology could be applied elsewhere if it were implemented.

### Statistical Methods

Baseline and treatment variables were summarized and stratified by construct type (screws-alone and anterior plate-screw fixation). Continuous variables were summarized as mean (SD), median (interquartile range) and range, and compared using *t* tests if approximately normal, or exact Wilcoxon rank sum test if otherwise. Categorical variables were summarized as frequency and percentage, and compared using $\chi^2$ tests, or Fisher exact tests if any expected cell counts were fewer than 5.

Cost outcomes were first adjusted to 2022 dollars according to Personal Consumption Expenditures (PCE),[1] then within each type of cost, divided by the sample median (of that specific type of cost). Because most people did not have imaging or laboratory costs, the median costs of these 2 types were zero. We dropped them from the report because they could not be anonymized. For the other costs, we summarized them stratified by fixation type and used exact Wilcoxon rank-sum tests to compare them between the 2 groups.

For total direct cost and facility costs, we used generalized linear models (glms) to compare them to treatment groups and other exposure variables. To determine the appropriate glm family, we examined their distributions visually using histograms, then we examined the mean-variance relationship conditional on exposure variables using the tweedie profile.[7,8] The inverse gaussian family with a log link was the most appropriate based on the tweedie profile. Goodness of fit was examined visually using simulated residuals.[11] The cost differences by exposure variables were reported as ratios with 95% CIs. For Table 1, data are presented as unadjusted normalized costs. For Table 2, the data are presented as ratios with screw only construct serving as the reference point (ie, ratios greater than 1 indicate greater costs in screw-plate constructs).

For Implant Cost, no family was appropriate because of extreme skewness, so we did not fit any regression models, and just used the exact Wilcoxon rank-sum test result for the conclusion. Significance was assessed at $P < .05$. All analyses were conducted in R,[25] and all tests were 2-sided.

Surgical outcomes were studied for both cohorts—specifically, reoperation rates for nonunion, infection, and hardware removal.

## Results

Our cohort consisted of 262 patients who underwent primary ankle fusion procedures performed by one of 4 fellowship-trained orthopaedic foot and ankle surgeons. Table 3 compared demographic data as well as treatment variables between the screws-alone group (n = 228) and the anterior plate-screw (n = 34) cohorts. Screws-alone constructs were performed either via the transfibular approach (n = 193) or arthroscopically (n = 35). There were no differences in demographic data or total OR time based on surgical construct. Not surprisingly, the number of screws between the groups was greater for the anterior plate-screws cohort with a mean of 7.9 (SD = 1.1) compared with the screws-alone cohort with a mean of 4.8 (SD = 1.1) ($P < .001$). The total OR time was not statistically different between groups with the screws-alone cohort having an average of 174 minutes

**Table 1.** Normalized Cost by Screws Alone and Plate/Screws.[a]

| Variable | Screws Alone (n = 228) | Plate/Screws (n = 34) | *P* Value |
|---|---|---|---|
| Total direct cost | | | |
| Mean (SD) | 1.1 (0.34) | 1.9 (0.57) | <.001[b] |
| Median (IQR) | 0.95 (0.84, 1.2) | 1.8 (1.6, 2.0) | |
| Range | 0.58, 2.5 | 1.0, 4.3 | |
| Facility cost | | | |
| Mean (SD) | 1.1 (0.44) | 1.3 (0.47) | .024[b] |
| Median (IQR) | 0.98 (0.79, 1.3) | 1.1 (0.88, 1.5) | |
| Range | 0.56, 3.3 | 0.69, 2.8 | |
| Other cost | | | |
| Mean (SD) | 1.3 (1.7) | 1.5 (1.7) | .22[b] |
| Median (IQR) | 0.99 (0.62, 1.4) | 1.1 (0.79, 1.6) | |
| Range | 0, 20 | 0, 9.7 | |
| Pharmacy cost | | | |
| Mean (SD) | 1.1 (0.63) | 1.3 (0.79) | .12[b] |
| Median (IQR) | 0.97 (0.72, 1.3) | 1.2 (0.85, 1.5) | |
| Range | 0.06, 5.6 | 0.09, 4.2 | |
| Implant cost | | | |
| Mean (SD) | 1.1 (0.68) | 4.0 (1.4) | <.001[b] |
| Median (IQR) | 0.96 (0.84, 1.1) | 3.4 (3.0, 4.9) | |
| Range | 0.45, 5.0 | 2.1, 7.1 | |
| Supply cost | | | |
| Mean (SD) | 1.4 (1.0) | 1.4 (1.9) | .054[b] |
| Median (IQR) | 1.0 (0.65, 1.8) | 0.64 (0.20, 1.5) | |
| Range | 0, 6.5 | 0, 7.1 | |

Abbreviation: IQR, interquartile range.
[a]Missing values by group: none.
[b]Exact Wilcoxon rank-sum test.

**Table 2.** Ratios in Total Direct Cost.

| | Univariable Model | | Multivariable Model | |
|---|---|---|---|---|
| Variable | Ratio (95% CI) | *P* Value | Ratio (95% CI) | *P* Value |
| Screw and plates vs screws alone | 1.77 (1.54, 2.07) | <.001 | 1.78 (1.55, 2.08) | <.001 |
| Age at surgery | 1.00 (1.00, 1.01) | .27 | 1.00 (1.00, 1.01) | .12 |
| Sex male vs female | 1.03 (0.93, 1.14) | .54 | 1.01 (0.93, 1.09) | .81 |
| BMI ≥30 vs <30 | 1.03 (0.93, 1.15) | .56 | 1.07 (0.98, 1.17) | .11 |
| Unknown vs <30 | 0.95 (0.83, 1.09) | .45 | 0.98 (0.88, 1.10) | .71 |
| White | 1.11 (0.91, 1.31) | .25 | 1.02 (0.87, 1.17) | .83 |
| Commercial insurance | 0.97 (0.88, 1.07) | .53 | 1.04 (0.96, 1.13) | .37 |
| ASA2 | 1.05 (0.88, 1.22) | .57 | 1.05 (0.92, 1.19) | .45 |
| ASA3-4 | 1.17 (0.97, 1.39) | .08 | 1.09 (0.94, 1.27) | .24 |
| Surgery setting: outpatient center vs main hospital | 0.81 (0.72, 0.91) | <.001 | 0.84 (0.75, 0.93) | .002 |
| Total OR time, hr | 1.29 (1.18, 1.40) | <.001 | | |

Abbreviations: ASA, American Society of Anesthesiologists Physical Status Classification System; BMI, body mass index; OR, operating room.

(SD = 35) and the plate-screw construct having an average of 180 minutes (SD = 46 minutes) (P = .92).

Table 1 examined unadjusted normalized cost differences between the screws-alone and anterior plate-screw cohorts. The median total direct cost was higher in the plate-screws group (1.8) compared with the screws-alone group (0.95, $P < .001$). The median implant cost was also higher for the plate-screws group (3.4) compared with the screws-alone group (0.96, $P < .001$). The facility cost was significantly lower in the screws alone group (P = .033).

**Table 3.** Demographic and Baseline Variables.[a]

| Variable | Screws Alone (n = 228) | Plate and Screws (n = 34) | *P* Value |
|---|---|---|---|
| Age at surgery | | | .33[b] |
| Mean (SD) | 58 (13) | 55 (16) | |
| Median (IQR) | 61 (51, 68) | 60 (40, 68) | |
| Range | 22, 83 | 22, 77 | |
| Sex, n (%) | | | .78[c] |
| Female | 93 (41) | 13 (38) | |
| Male | 135 (59) | 21 (62) | |
| BMI | | | .24[b] |
| Mean (SD) | 31 (6.0) | 31 (6.1) | |
| Median (IQR) | 31 (27, 35) | 29 (26, 32) | |
| Range | 20, 49 | 22, 45 | |
| Missing, n (%) | 43 (19) | 6 (18) | |
| BMI category, n (%) | | | .45[c] |
| $<$30 | 76 (33) | 15 (44) | |
| $\geq$30 | 109 (48) | 13 (38) | |
| Unknown | 43 (19) | 6 (18) | |
| Race, n (%) | | | .56[d] |
| American Indian and Alaska Native | 3 (1.3) | 0 (0) | |
| Black or African American | 1 (0.44) | 0 (0) | |
| Chose not to disclose | 4 (1.8) | 2 (5.9) | |
| Other | 11 (4.8) | 2 (5.9) | |
| Other Pacific Islander | 2 (0.88) | 0 (0) | |
| White or Caucasian | 206 (91) | 30 (88) | |
| Missing | 1 (0.44) | - | |
| White race,[e] n (%) | 206 (92) | 30 (94) | $>$.99[d] |
| Missing | 5 (2.2) | 2 (5.9) | |
| Insurance, n (%) | | | .65[d] |
| Commercial | 122 (54) | 17 (50) | |
| Government (other) | 10 (4.4) | 1 (2.9) | |
| Medicaid | 6 (2.6) | 2 (5.9) | |
| Medicare | 82 (36) | 12 (35) | |
| Self-pay | 1 (0.44) | 0 (0) | |
| Worker's compensation | 7 (3.1) | 2 (5.9) | |
| Commercial insurance, n (%) | 122 (54) | 17 (50) | .70[c] |
| ASA class, n (%) | | | .70[d] |
| 1 | 23 (10) | 4 (12) | |
| 2 | 142 (63) | 19 (56) | |
| 3-4 | 62 (27) | 11 (32) | |
| Missing | 1 (0.44) | – | |
| Total OR time | | | .92[b] |
| Mean (SD) | 174 (35) | 180 (46) | |
| Median (IQR) | 170 (151, 193) | 162 (151, 196) | |
| Range | 97, 303 | 135, 334 | |
| Hardware removed during ankle fusion, n (%) | 39 (17) | 8 (24) | .36[c] |
| Achilles lengthening, n (%) | 10 (4.4) | 1 (2.9) | $>$.99[d] |
| Surgical location, n (%) | | | .95[c] |
| Main hospital | 48 (21) | 7 (21) | |
| Outpatient center | 180 (79) | 27 (79) | |
| No. of screws | | | $<$.001[b] |
| Mean (SD) | 4.8 (1.1) | 7.9 (1.1) | |
| Median (IQR) | 5.0 (5.0, 5.0) | 8.0 (7.0, 8.8) | |
| Range | 2.0, 7.0 | 6.0, 10.0 | |

*(continued)*

**Table 3. (continued)**

| Variable | Screws Alone (n = 228) | Plate and Screws (n = 34) | *P* Value |
|---|---|---|---|
| No. of plates | | | <.001[b] |
| Mean (SD) | 0 (0) | 1.0 (0) | |
| Median (IQR) | 0 (0, 0) | 1.0 (1.0, 1.0) | |
| Range | 0, 0 | 1.0, 1.0 | |

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; IQR, interquartile range; OR, operating room.
[a]Missing values by group: BMI = 43 (19%) / 6 (18%), race = 1 (0.44%)/0 (0%), ASA = 1 (0.44%)/0 (0%).
[b]Exact Wilcoxon rank-sum test.
[c]$\chi^2$ test.
[d]Fisher exact test.
[e]White race = 5 (2.2%) / 2 (5.9%).

**Table 4.** Reoperation Rates for Screw-Only vs Anterior Fusion Constructs.

| Variable | Screws Alone, n (%) (n = 228) | Plate/Screws, n (%) (n = 34) |
|---|---|---|
| Reoperation for nonunion | 18 (7.9) | 1 (2.9) |
| Reoperation for hardware removal | 50 (21.9) | 7 (20.6) |
| Reoperation for infection | 7 (3.1) | 1 (2.9) |

Table 2 shows the ratios in total direct costs in both univariable and multivariable inverse gaussian regression analysis. Total direct cost for anterior plate-screw constructs were 78% higher than screws alone (ratio in cost = 1.78, 95% CI 1.55-2.08, $P < .001$), adjusting for other variables. For all fusion constructs, in a univariable analysis, every 1-hour increase in total OR time increased total direct costs by 29% (ratio in cost = 1.29, 95% CI 1.18-1.40, $P < .001$).

Table 4 demonstrates the number of patients who underwent revision surgery for nonunion, hardware removal, and infection. There were no differences ($P > .1$) between anterior-plate or screw-only constructs for all 3 variables studied.

## Discussion

The purpose of this study was to evaluate the surgical costs associated with tibiotalar arthrodesis. Our investigation retrospectively compared 2 common fixation methods: screws-alone vs anterior plate-screw fixation. The results indicate that the choice of fixation technique significantly impacts the overall costs of the procedure with no apparent impact on outcomes. We found that the total direct cost for plate-screw constructs was 78% higher than screws-alone constructs. This finding suggests that using screws-alone constructs could significantly reduce overall total costs, when clinically appropriate.

Several limitations of our study should be acknowledged. First, this study was retrospective, and there may be unmeasured confounders that could influence the results. Furthermore, the sample size for the plate-screws group was notably smaller than the screw-only cohort, which may limit the generalizability of our findings. At our institution, we clearly have a historical predilection toward a screw-only construct, but over recent years have expanded our use of screw-plate constructs. Deciding on the appropriate surgical construct must weigh patient-specific variables including deformity, available bone stock and quality, body habitus, and soft tissue envelope, among many factors. We believe both constructs have a role in modern ankle fusion surgery. Although we did not see a difference in outcomes regarding reoperation risk, our findings—because of the smaller sample of anterior fusion constructs—could be statistically fragile. The goal of this report was to understand costs surrounding the episode of care for an ankle fusion (ie, day of surgery costs) and was not aimed to perform either a cost analysis or true outcomes study.

Missing data are also a limitation in our cohort as 16 of 34 (47%) anterior-plating patients did not have minimum 6-month postoperative radiographs compared with 51 of 229 screw-only constructs (22%). Of those patients who had at least 6-month radiographs, radiographic union was seen in 90% of screw-only constructs and 94% of anterior-plate constructs. However, we would strongly caution on interpreting these data because of the large portion of missing radiographs, imbalance in the missing data (greater number of missing data in the plating construct), and statistical fragility of the plating construct data. For example, an additional radiographic nonunion in the plating construct would shift the nonunion rate to 88%. Given the aforementioned factors, we feel that we cannot comment on differences (or similarities) in union rates based on surgical construct. Further, the purpose of our study was to assess episode of care cost and not a long-term follow-up study of ankle fusions vs cost at our center. Lastly, we should note that our elective hardware removal rates after fusion are relatively high, regardless of construct. A possible explanation may include activity preferences in our practice region with screws and/or plates potentially more symptomatic in winter sports that require ski boots.

Our findings are consistent with previous research. Hyer et al (2008) examined the costs of crossed screws vs dorsal plating for first metatarsophalangeal joint arthrodesis.[12] They discovered that the mean crossed screws construct ($374.05 ± $76.3) was considerably cheaper than the dorsal plating technique ($603.57 ± $234.7), which was strongly significant ($P = .0002$). Similarly, our study found that total direct costs ($P < .001$) as well as implant costs ($P < .001$) were significantly higher for the anterior plate-screws cohort compared to the screws-alone group in relative cost analysis.

Multiple prior studies have explored tibiotalar union rates based on surgical construct. Studies have largely found no statistical differences in nonunion rates comparing compression screws to anterior plating for ankle fusions.[10,13,17,22,27,31,35] For surgeons practicing in an environment with a particular emphasis on health care costs, a screw-only construct for tibiotalar fusions may achieve notable reductions in cost relative to anteriorly based plates. In our practices, we use both constructs with decision making tailored to the specific patient.

In conclusion, our study demonstrates that screw-only surgical constructs for tibiotalar arthrodesis are associated with significantly lower overall total costs compared with anterior plate-screw constructs. The cost difference is mostly due to a cheaper implant cost for screw-only surgical constructs. Many variables are considered when selecting surgical constructs for ankle arthrodesis. When clinically appropriate, screw-only ankle arthrodesis constructs could be considered if there is a need to reduce overall costs.

## Ethical Approval

Ethical approval for this study was obtained from the University of Utah. Approval number IRB_00071733. The title for the IRB is "EXEMPTION UMBRELLA: Value of the treatment of musculoskeletal disorders at the University of Utah Covered Entity for lower extremity pathologies."

## Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. Disclosure forms for all authors are available online.

## Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This investigation was supported by the University of Utah Study Design and Biostatistics Center, with funding in part from the National Center for Research Resources and the National Center for Advancing Translational Sciences, National Institutes of Health, through Grant UM1TR004409.

## ORCID iD

Devon Nixon, MD, https://orcid.org/0000-0003-1328-026X

## References

1. US Bureau of Economic Analysis. Table 2.5.4. Price indexes for personal consumption expenditures by function. Accessed February 6, 2024. https://apps.bea.gov/iTable/?reqid=19&step=3&isuri=1&nipa_table_list=62&categories=survey#eyJhcHBpZCI6MTksInN0ZXBzIjpbMSwyLDNdLCJkYXRhIjpbWyJuaXBhX3RhYmxlX2xpc3QiLCI3MyJdLFsiY2F0ZWdvcmllcyIsIlN1cnZleSJdXX0=
2. Abidi NA, Gruen GS, Conti SF. Ankle arthrodesis: indications and techniques. *J Am Acad Orthop Surg*. 2000;8(3):200-209.
3. Adukia V, Mangwani J, Issac R, Hussain S, Parker L. Current concepts in the management of ankle arthritis. *J Clin Orthop Trauma*. 2020;11(3):388-398.
4. Agel J, Coetzee JC, Sangeorzan BJ, Roberts MM, Hansen ST Jr. Functional limitations of patients with end-stage ankle arthrosis. *Foot Ankle Int*. 2005;26(7):537-539.
5. Burnham JM, Meta F, Lizzio V, Makhni EC, Bozic KJ. Technology assessment and cost-effectiveness in orthopedics: how to measure outcomes and deliver value in a constantly changing healthcare environment. *Curr Rev Musculoskelet Med*. 2017;10:233-239.
6. DeHeer PA, Catoire SM, Taulman J, Borer B. Ankle arthrodesis: a literature review. *Clin Podiatr Med Surg*. 2012;29(4):509-527.
7. Dunn PK. Tweedie: Evaluation of Tweedie exponential family models. R package version 2.3. 2022. Accessed February 6, 2024. https://rdrr.io/cran/tweedie/
8. Dunn PK, Smyth G. Series evaluation of Tweedie exponential dispersion models. University of Southern Queensland; 2002.
9. El-Alfy B. Arthrodesis of the ankle joint by Ilizarov external fixator in patients with infection or poor bone stock. *Foot Ankle Surg*. 2010;16(2):96-100.
10. Goh TS, Han JB, Lee SM, Kang SW, Shin WC, Woo SH. Screw only versus screw plus plate in isolated talonavicular arthrodesis. *Foot Ankle Surg*. 2022;28(7):1045-1049.
11. Hartig F. Residual diagnostics for hierarchical (multi-level/mixed) regression models. R package version 0.4.6. https://CRAN.R-project.org/package=DHARMa
12. Hyer CF, Glover JP, Berlet GC, Lee TH. Cost comparison of crossed screws versus dorsal plate construct for first metatarsophalangeal joint arthrodesis. *J Foot Ankle Surg*. 2008;47(1):13-18.
13. Izzo A, Sgadari A, Coviello A, et al. Does the number of screws influence the union rate in ankle arthrodesis? A meta-analysis and systematic review. *Foot Ankle Spec*. 2023;0(0). doi:10.1177/19386400231171508
14. Kawamoto K, Martin CJ, Williams K, et al. Value Driven Outcomes (VDO): a pragmatic, modular, and extensible software framework for understanding and improving health care costs and outcomes. *J Am Med Inform Assoc*. 2015;22(1):223-235.

15. Kazmers NH, Judson CH, Presson AP, Xu Y, Tyser AR. Evaluation of factors driving cost variation for distal radius fracture open reduction internal fixation. *J Hand Surg*. 2018;43(7):606-614.e1.
16. Kazmers NH, Presson AP, Xu Y, Howenstein A, Tyser AR. Cost implications of varying the surgical technique, surgical setting, and anesthesia type for carpal tunnel release surgery. *J Hand Surg*. 2018;43(11):971-977.e1.
17. Kennedy JG, Hodgkins CW, Brodsky A, Bohne WH. Outcomes after standardized screw fixation technique of ankle arthrodesis. *Clin Orthop Relat Res*. 2006;447:112-118.
18. Kim HJ, Suh DH, Yang JH, et al. Total ankle arthroplasty versus ankle arthrodesis for the treatment of end-stage ankle arthritis: a meta-analysis of comparative studies. *Int Orthop*. 2017;41:101-109.
19. Lawton CD, Butler BA, Dekker RG, Prescott A, Kadakia AR. Total ankle arthroplasty versus ankle arthrodesis—a comparison of outcomes over the last decade. *J Orthop Surg Res*. 2017;12:1-10.
20. Lee VS, Kawamoto K, Hess R, et al. Implementation of a value-driven outcomes program to identify high variability in clinical costs and outcomes and association with reduced cost and improved quality. *JAMA*. 2016;316(10):1061-1072.
21. Martin RL, Stewart GW, Conti SF. Posttraumatic ankle arthritis: an update on conservative and surgical management. *J Orthop Sports Phys Ther*. 2007;37(5):253-259.
22. Mitchell PM, Douleh DG, Thomson AB. Comparison of ankle fusion rates with and without anterior plate augmentation. *Foot Ankle Int*. 2017;38(4):419-423.
23. Myerson MS, Alvarez RG, Lam PW. Tibiocalcaneal arthrodesis for the management of severe ankle and hindfoot deformities. *Foot Ankle Int*. 2000;21(8):643-650.
24. Prissel MA, Simpson GA, Sutphen SA, Hyer CF, Berlet GC. Ankle arthrodesis: a retrospective analysis comparing single column, locked anterior plating to crossed lag screw technique. *J Foot Ankle Surg*. 2017;56(3):453-456.
25. R Foundation for Statistical Computing. R: A Language and Environment for Statistical Computing. 2023. https://www.R-project.org/
26. Raikin SM, Rasouli MR, Espandar R, Maltenfort MG. Trends in treatment of advanced ankle arthropathy by total ankle replacement or ankle fusion. *Foot Ankle Int*. 2014;35(3):216-224.
27. Slater GL, Sayres SC, O'Malley MJ. Anterior ankle arthrodesis. *World J Orthop*. 2014;5(1):1.
28. Smyth NA, Dawkins BJ, Goldstein JP, Kaplan JR, Schon LC, Aiyer AA. Consumer prices for surgical management of ankle arthritis: limited availability and wide variability. *J Am Acad Orthop Surg Glob Res Rev*. 2019;3(7):e011.
29. SooHoo NF, Zingmond DS, Ko CY. Comparison of reoperation rates following ankle arthrodesis and total ankle arthroplasty. *J Bone Joint Surg Am*. 2007;89(10):2143-2149.
30. Thomas R, Daniels TR, Parker K. Gait analysis and functional outcomes following ankle arthrodesis for isolated ankle arthritis. *J Bone Joint Surg Am*. 2006;88(3):526-535.
31. van den Heuvel SB, Doorgakant A, Birnie MF, Blundell CM, Schepers T. Open ankle arthrodesis: a systematic review of approaches and fixation methods. *Foot Ankle Surg*. 2021;27(3):339-347.
32. Vickerstaff JA, Miles AW, Cunningham JL. A brief history of total ankle replacement and a review of the current status. *Med Eng Phys*. 2007;29(10):1056-1064.
33. Yasui Y, Hannon CP, Seow D, Kennedy JG. Ankle arthrodesis: a systematic approach and review of the literature. *World J Orthop*. 2016;7(11):700.
34. Zulauf EE, Prissel MA. Ankle fusion outcomes utilizing anterior ankle plating techniques: a systematic review. *Foot Ankle Surg Tech Rep Cases*. 2023:3;100287.
35. Zwipp H, Rammelt S, Endres T, Heineck J. High union rates and function scores at midterm followup with ankle arthrodesis using a four screw technique. *Clin Orthop Relat Res*. 2010;468(4):958-968.