

Comparison of the Costs of Reusable Versus Disposable Equipment for Endoscopic Carpal Tunnel Release Procedures Using Activity-Based Costing Analysis

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Purpose Guidelines for sterilization of reusable equipment (eg, arthroscopes, surgical equipment) have recently been established. These guidelines are supported by the U.S. Food and Drug Administration and affect costs for sterilization. The current analysis was undertaken to understand if reusable or disposable endoscopic carpal tunnel release (ECTR) equipment is a less-expensive option.

Methods An activity-based cost analysis was undertaken to determine the costs of reusable versus disposable equipment for ECTR. Costs of disposable equipment were obtained from manufacturers. Costs of processing reusable equipment including labor, time, cost of operating room time, and sterilization supplies and equipment were obtained from the literature and from recent reports identifying these costs. Infection rates and costs of infection were also factored in. Decision analysis software was used to determine the expected costs of each option (disposable vs reusable). A sensitivity analysis was undertaken on those variables that were determined to have the greatest effect on the overall costs of the procedure and sterilization.

Results Costs for each option when totaled were \$917 for disposable and \$1,019 for reusable equipment, resulting in cost savings of \$102 with disposable equipment. Reusable equipment was the least costly option when the following costs/events occurred: cost of a disposable arthroscope, >\$452; cost of disposable ECTR, >\$647; costs of operating room time, <\$28.63/min; set up time, <6.8 minutes for reusable equipment; and cost of disposable ECTR blade used with reusable equipment, <\$160.

Conclusions When considering the cost of operating room time, preparation, and processing of reusable equipment for ECTR, the disposable equipment for this procedure is less costly. (*J Hand Surg Am.* 2020; ■(■):1.e1-e15. Copyright © 2020 by the American Society for Surgery of the Hand. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).)

Type of study/level of evidence Economic Analysis II.

Key words Endoscopic, reusable, disposable, cost.



VALUE IN HEALTH CARE DELIVERY is defined as a clinical outcome per dollars spent. Optimizing value comes not only from understanding outcomes but also from a granular and disciplined understanding of cost drivers. An area in

which costs have been a focus is with time-driven, activity-based costing, which allows for the characterization of procedural costs including pre-, intra-, and postprocedure.^{1,2} Reprocessing/sterilization updates have recently taken place with reusable

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endoscopes³ and include such items as immediate postuse cleaning (or bedside precleaning), inspection, personal protective equipment, and transportation to sterilization. These updates also include drying, storage, and proper documentation of reusable equipment. The reprocessing of reusable equipment has become more extensive owing to infections associated with these types of devices/equipment, and the difficulty in cleaning/sterilizing them and has resulted in the U.S. Food and Drug Administration (FDA) requesting reprocessing instructions in 510(k) submissions.⁴ In orthopedic surgery, this most notably includes arthroscopes and accessories.

Further, operating room costs are an important component that should be considered when evaluating reusable versus disposable equipment. It has been noted in previous studies that the direct (eg, wages, benefits, operating room supplies, purchased services) and indirect (eg, utilities, security, interest, insurance, housekeeping, laundry) costs per minute can be \$36 to \$38.⁵ Thus, efficient use of the operating room (including time for set up of reusable equipment) should also be considered when comparing costs associated with reusable and disposable equipment.

The purpose of this analysis was to utilize activity-based cost methodology with the national standards guidelines³ for the reprocessing of reusable equipment utilized in endoscopic carpal tunnel release (ECTR) and to compare these costs with the cost of using single-use surgical ECTR and imaging equipment (Trice Medical, King of Prussia, PA). It is also an opportunity to identify specific cost drivers and how sensitive they are to the types of resources utilized. Prior research using activity-based costing has demonstrated that ECTR is more expensive than open carpal tunnel release (OCTR).⁶ It is the purpose of this analysis to identify which of the alternative disposable versus reusable equipment may be the less-expensive option in ECTR. It is also an opportunity to identify specific cost drivers in these options and determine how sensitive these drivers are to the types and quantity of resources utilized.

METHODS

Costs of reusable and disposable equipment were collected from sources identified in a systematic review of the literature and from various companies that provide this type of equipment.

The systematic review used the following search terms: endoscopic and carpal tunnel release and cost-

effectiveness; reusable and reprocess* and cost effective and *scope.

The following electronic databases were searched:

- PubMed Central
- Google (first 4 pages of hits)
- American National Standards Institute (ANSI)

The cost of using reusable equipment was calculated using several components. First, the cost of the capital purchase, expected useful life of the equipment, and the number of expected uses over the lifetime of the capital equipment were utilized to calculate a use per case cost. Second, the cost of maintenance and repair/refurbishment of the equipment (mainly the scope) and for the cost of a backup system, in case the primary system was not functional. Third, the cost of reprocessing, which was estimated using the ANSI/AAMI (Australian Associated Motor Insurers) Standard 91 guidelines.³ With reprocessing, a time-based activity per cost was utilized, which included both materials and labor. Times for each activity involved in reprocessing were derived from a recent analysis on the reprocessing costs for endoscopes.⁷ Fourth, there is the time for the setup necessary in the operating room for the reusable equipment—again employing materials and labor necessary to do so.

Costs for labor assumed a range of different types of labor including central service reprocessing, surgical technologists, and nurses. In addition, material costs varied based on a level of sterilization security (eg, single vs double gloves) and manufacturer prices.

The costs per minute for the operating room were derived from sources that examined costs in ambulatory settings, mainly not-for-profit and academic teaching hospitals, and ranged from \$36.14 to \$41.93.^{5,6} Further, it was assumed that an ECTR procedure would take 48 to 60 minutes including the entire perioperative period (preoperative, intraoperative). Set up time for reusable equipment was estimated at 10 minutes.⁶

The variables and distributions used in the analysis can be found [Appendix A](#) (available on the *Journal's* Web site at www.jhandsurg.org) and were utilized in decision analysis software (TreeAge Pro, 2019). [Appendix B](#) (available on the *Journal's* Web site at www.jhandsurg.org) shows the decision tree along with the equations used in the decision tree. The variables and their base case costs used in the decision analysis are shown in [Table 1](#).

Tree Age Pro software was also used for sensitivity analyses examining which variables and their ranges had the greatest effect on the overall cost of reusable and single use equipment for ECTR. As well, the Consolidated Health Economic Evaluation

TABLE 1. Base Case Values Used in TreeAge Pro Decision Tree

Variable	Base Case	References
Operating room cost per min	\$38.86	5
Time in min to set up reusable equipment	Most likely: 10; range of 4–16 min	6
Cost per use of reusable scope	\$21.81 (\$4,700/215.5 uses)	8
Cost per use of reusable carpal tunnel capital equipment	\$9.28 (\$3,995/215.5 uses)	6,9
Cost of disposable scope	\$350	9
Cost of disposable ECTR equipment	\$545	9
Cost of disposable blade (Microaire)	\$225–\$300	10
Infection rate owing to reusable equipment	0.5%	11

Reporting Standards (CHEERS) checklist was used to ensure good reporting practices in economic analysis were followed (Appendix C; available on the *Journal's* Web site at www.jhandsurg.org). All costs used were assumed to be present day.

RESULTS

Figure 1 shows the results of the systematic review. Four articles were used in the analysis for costing of reusable versus disposable ECTR.^{5–8}

At a price of \$350 for the disposable arthroscope and \$545 for the disposable ECTR equipment, the overall per use cost was higher with the reusable compared with the disposable equipment by \$102 per case (\$1,019 vs \$917, respectively). Sensitivity analysis (Tree Age Pro) showed the variables and the value at which reusable equipment became the less costly alternative (Fig. 2 [Tornado Plot] and Table 2). The tornado plot identifies those variables that have the greatest effect on the cost comparison (ie, when varied would change the conclusion of the cost analysis toward using reusable equipment). The tornado plot includes a range of values that are identified by the low and high values of the bars in the plot. In addition, the black vertical line in each bar identifies the value at which the reusable equipment becomes the less-expensive option.

For each of the variables for which there was a value identified resulting in the reusable option to be the less-expensive option, the amount identified was greater than 25% of the base case. In other words, the assumptions used in the analysis for base cases are the values likely encountered in everyday/standard practice when using ECTR. Thus, in order for the reusable option to be the less-expensive option, a significant deviation from ECTR standard practice would need to occur (Figs. E1–E5—available on the *Journal's* Web site at www.jhandsurg.org—provide

further detail). For the single-use option, ECTR would need to be greater than 18% of the base case.

Two-way sensitivity analysis of operating room cost per minute and time spent setting up reusable equipment demonstrates that as the cost per operating room minute increases, set up time needs to be reduced in order for reusable equipment to be the less costly option (Fig. 8). At a cost per minute of operating room set up time of <\$28.63, operating room technicians can take 10 minutes or more in setting up the reusable equipment in the operating room and still be less expensive than the disposable option.

DISCUSSION

Based upon our evaluation, when examining costs via time-driven activity-based costing, and applying the ANSI guidelines for reprocessing, the costs for reprocessing/sterilizing reusable equipment and setup can be upward of \$1,020 per case. The FDA is requiring, as part of the 21st Century Cures Act, that manufacturers include validated instructions for use in the cleaning and sterilization as part of any 510(k) submission. This is largely due to the evolution toward more complex reusable medical device designs that are more difficult to clean, disinfect, and sterilize.⁴ Although the ANSI standards for pre-cleaning, leak-testing, cleaning, packaging (where indicated), storage, high-level disinfecting, and/or sterilizing of scopes in health care facilities are voluntary, the standards are intended to provide comprehensive information and direction for health care personnel in the processing of these devices and accessories.³ This was also recognized by the FDA as a consensus standard for reprocessing in 2015.⁶

In the sensitivity analysis, one of the main cost drivers identified with reusable equipment was the operating room costs associated with equipment set up. A prior time-driven activity-based costing

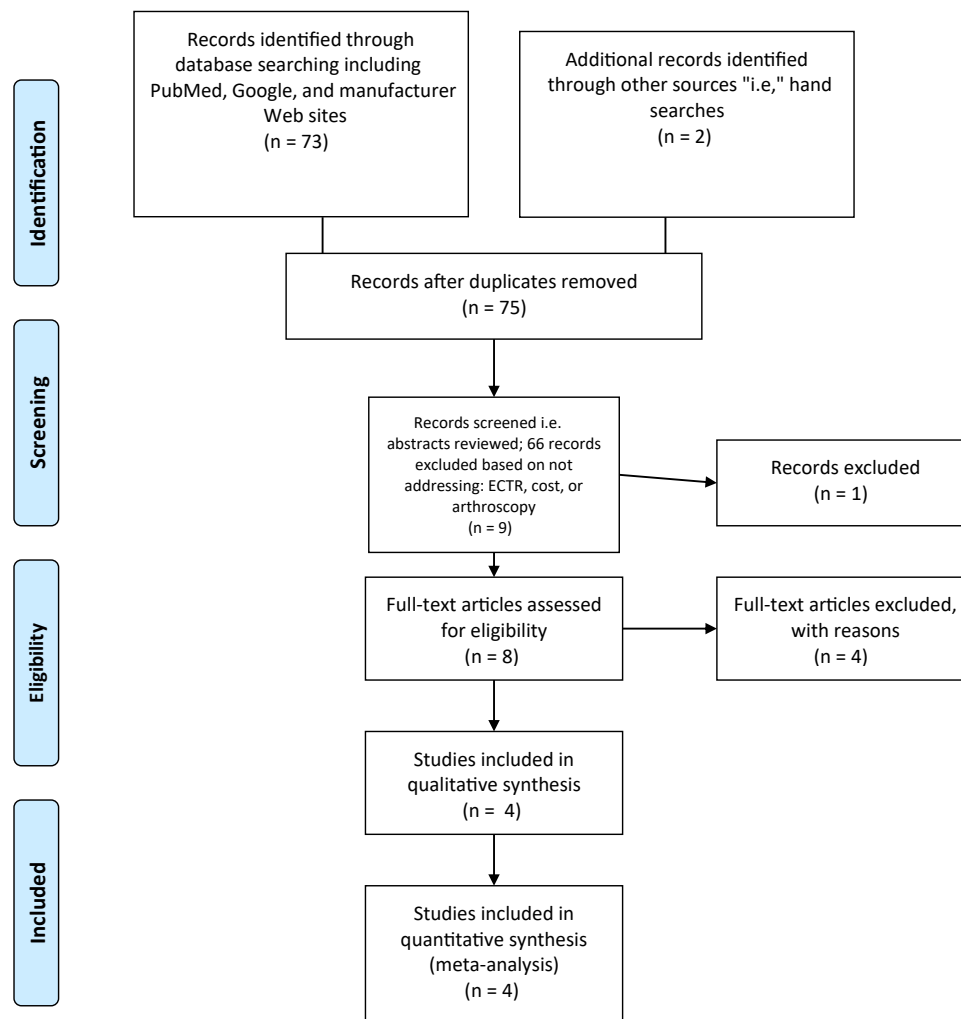


FIGURE 1: PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram. Systematic review summary of articles used in this manuscript. (From Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA statement. *PLoS Med.* 2009;6(7):e1000097. For more information, visit www.prisma-statement.org.)

showed that an ECTR procedure lasted 48 to 60 minutes,^{6,9} which included preprocedure setup and intraoperative time. Assuming a 10-minute set up time for the reusable equipment, a \$361.40 to \$413.90 total cost ($\$36.10 \times 10$ minutes; $\$41.39 \times 10$ minutes) was associated with this activity. Prior studies have shown a variable cost per minute in the operating room for abdominal surgery of \$29.25,¹⁰ \$36 to \$38/min for all types of surgery (inpatient and outpatient)⁵ and \$51/min for knee arthroplasty.¹¹ If the time for set up of reusable equipment exceeds 7.4 minutes, then the use of disposable equipment becomes the less-expensive option. Further, if the operating room cost per minute exceeds \$28.63, again the disposable option becomes less expensive. Even while using a reusable setup, there are some components that need to be disposable. For example, in ECTR, a new, disposable, blade is used on each

case. The purchase price of a disposable blade used as part of a reusable equipment setup is commonly in the \$225 to \$300 range (average price, \$262). In order for the reusable equipment option to be the less costly option, a price of <\$160 for the disposable blade would be required.

Prior research in activity-based costing analyzing ECTR with OCTR has shown that OCTR is the less-expensive option.⁶ The main cost drivers identified in that study were orthopedic surgeon labor/time (32.7 [ECTR] vs. 21.3 [OCTR] minutes); intraoperative case duration (44.8 [ECTR] vs. 40.5 [OCTR] minutes), and time for central sterilization (57 [ECTR] vs. 34 [OCTR] minutes). Not taken account of were downstream sequelae (such as wound problems [infections, wound dehiscence, hematoma],¹² scar-related,⁸ and long-term structural nerve, artery, and tendon injury^{8,13}), which have been found to be

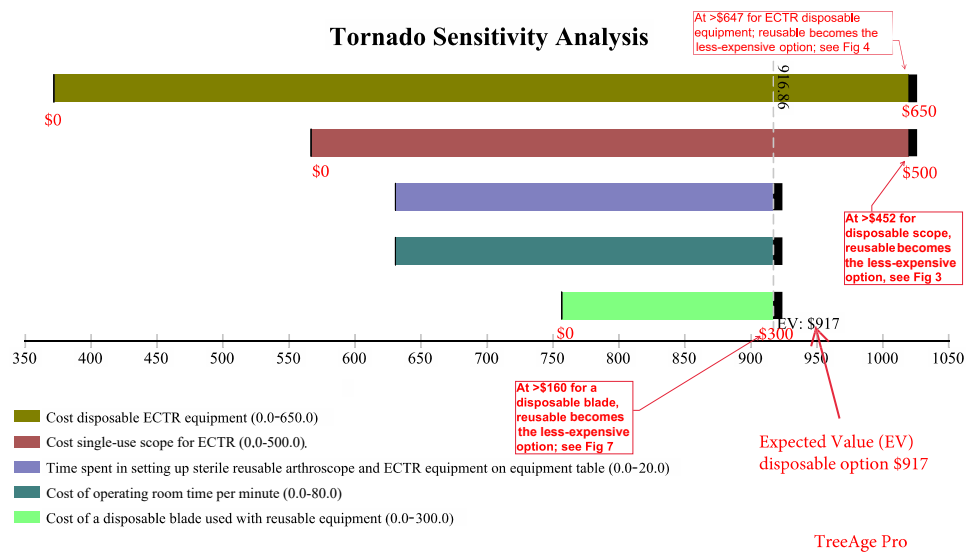


FIGURE 2: Tornado plot identifying those variables with greatest effect on costs.

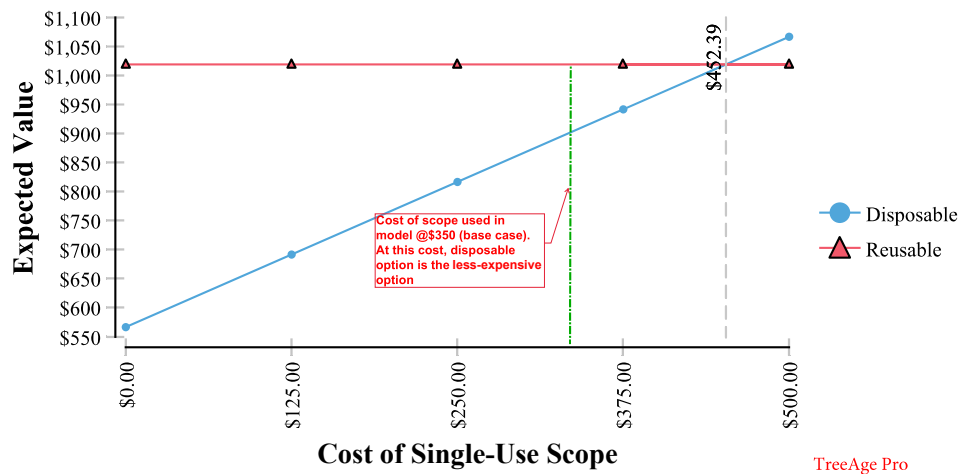


FIGURE 3: Sensitivity analysis. Cost at which the single-use arthroscope was the most-expensive alternative. With all other variables held constant, and varying the cost of a single-use arthroscope, at a cost of >\$452, the expected overall cost for the disposable option (expected value; y axis) would be the more-expensive alternative (versus reusable).

higher in OCTR.^{8,13,14} Further, it has been noted that there may be a reporting bias regarding complications associated with the open approach.¹⁴ The current analysis only analyzed the differential in infection rates between reusable versus disposable and only as they directly related to resterilization issues. Although it was not the intent of this analysis to address downstream sequelae in this analysis of reusable versus disposable ECTR equipment (except for infections), the previous findings that OCTR is a less-expensive option than ECTR should be borne in mind. Ultimately, however, the decision to use the endoscopic or the open approach for carpal tunnel release may be more dependent upon surgeon and patient personal preference than the overall cost.

Our study examines the costs associated with reprocessing and reuse of capital equipment in the operating room using recommended ANSI standards for reprocessing. It also demonstrates that it may be possible to reduce these costs by using disposable ECTR equipment. It may also be safer to use disposable equipment considering the risk of infection with ECTR, which has been reported to be in the range of 1.2% in a large series of patients treated using reusable equipment.¹⁵ An infection rate of 0.5% (range, 0.25%–0.75%) has been associated with current sterilization methods for arthroscopes.¹¹ A recent study has shown that inadequate reprocessing and insufficient drying contributed to over three-quarters of all scopes exhibiting microbial

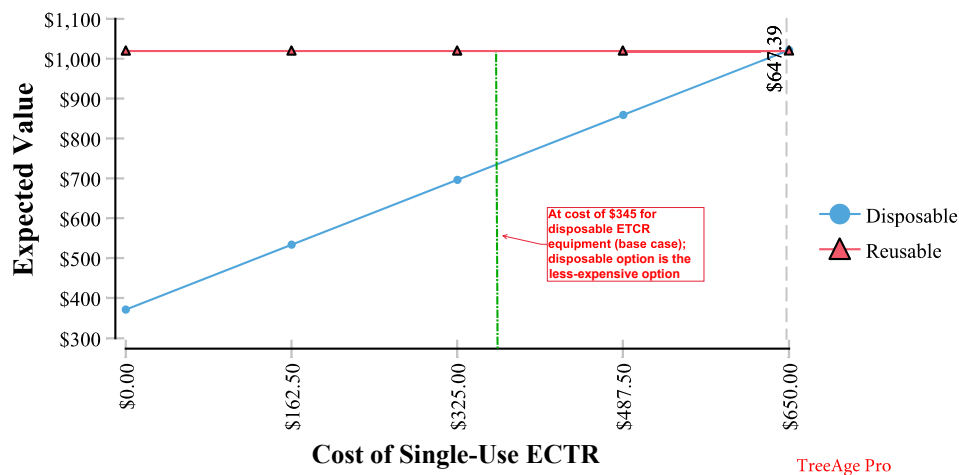


FIGURE 4: Sensitivity analysis. Cost at which the ECTR disposable was the most-expensive alternative. With all other variables held constant, and varying the cost of a single-use ECTR, at a cost of $> \$647$, the expected overall cost for the disposable option (expected value; y axis) would be the more-expensive alternative (versus reusable).

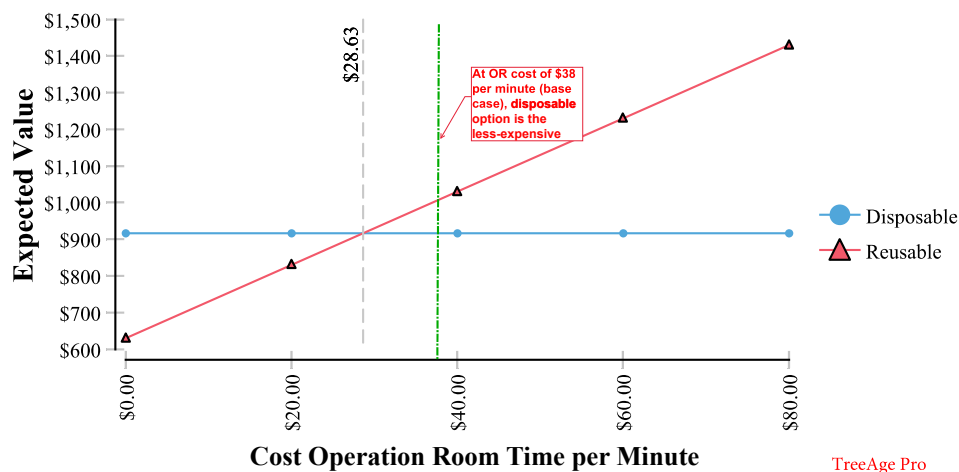


FIGURE 5: Sensitivity analysis. Cost per minute of operating room time in which the reusable option was the less-expensive alternative. With all other variables held constant, and varying the cost per minute of operating room time, at a cost of $< \$28.63/\text{min}$ of operating room time, the expected overall cost for the disposable option (expected value; y axis) would be the more-expensive alternative (versus reusable).

growth,¹³ which likely contributes to the infection rate seen in reusable scope procedures.

This analysis was performed using data from other studies. It would be reasonable to perform a time-driven activity-based analysis prospectively comparing disposable versus reusable ECTR equipment. The costs per minute of operating room time that were used are generally reflective of the type of surgery performed in the operating room and its intensity of services required. Because this is strictly a cost-comparison analysis, physician and patient satisfaction were not evaluated.

It was assumed that a backup system and its associated cost were required for the procedure. However, in practice, the procedure could be converted to an

open procedure negating the need for a backup system in case of malfunction. The backup system cost was included in both arms of the analysis.

Costs for disposal of single-use disposable equipment were not addressed in this analysis. Further longer-term costs associated with medical waste management were not addressed.

Hospital infection rates are generally underreported in the literature for numerous reasons including a lack of proper surveillance and a lack of a common nomenclature.^{16,17} A prospective study comparing downstream complication rates of reusable versus disposable equipment would be warranted.

Based on this analysis, it would appear reasonable from a cost-savings perspective to use disposable

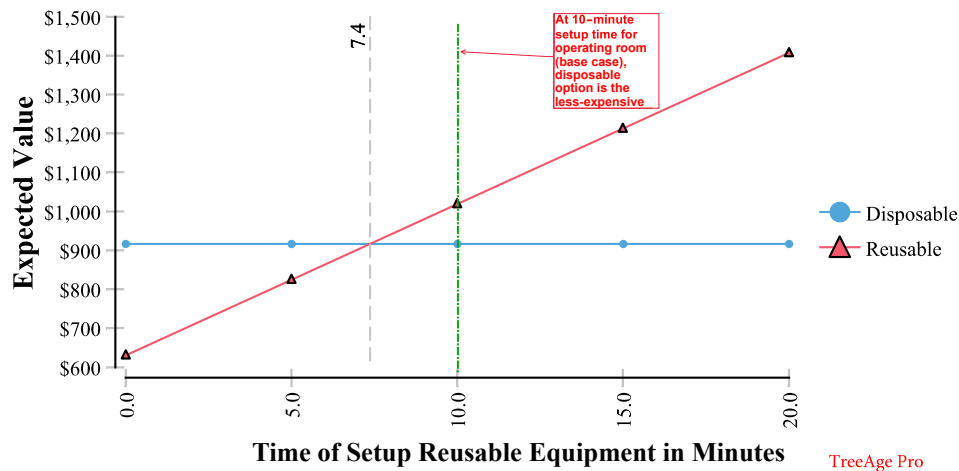


FIGURE 6: Sensitivity analysis: Time in minutes for reusable setup became the less-expensive alternative. This demonstrates that, at a time of <7.4 minutes for reusable setup time, the expected overall cost for the disposable option (expected value; y axis) would be the more-expensive alternative (versus reusable).

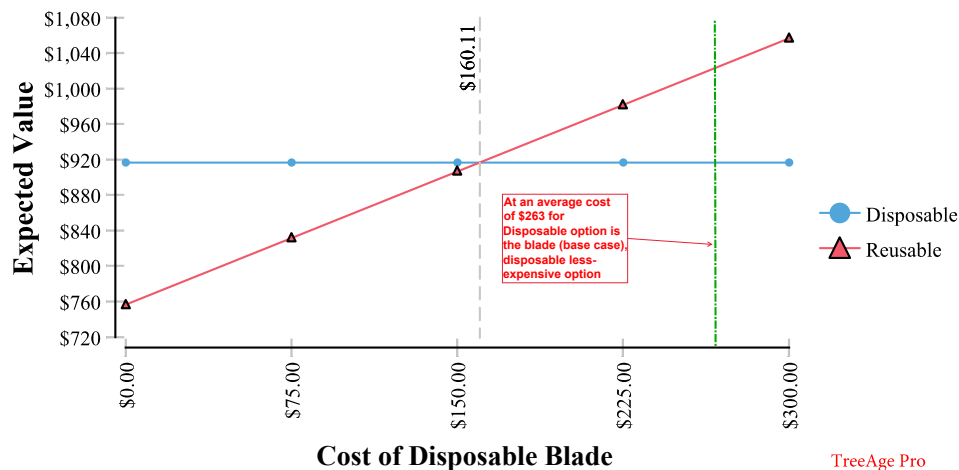


FIGURE 7: Sensitivity analysis. Cost for disposable blade at which the reusable option becomes the less-expensive alternative. With all other variables held constant, and varying the cost of a disposable blade, at a cost of >\$160 for the disposable blade, the expected overall cost for the disposable option (expected value; y axis) would be the more-expensive alternative (versus reusable).

TABLE 2. Sensitivity Analysis

Variable	Base Case	Value in Sensitivity Analysis at Which Reusable Becomes Less Costly
Single-use arthroscope	\$350	>\$452 (Fig. 3)
Single-use ECTR	\$545	>\$647 (Fig. 4)
Cost of operating room time per min	\$38.86	<\$28.63 (Fig. 5)
Set up time for reusable scope and ECTR equipment (min)	10	<7.4 (Fig. 6)
Cost of disposable blade (Microaire)	\$262	<\$160 (Fig. 7)

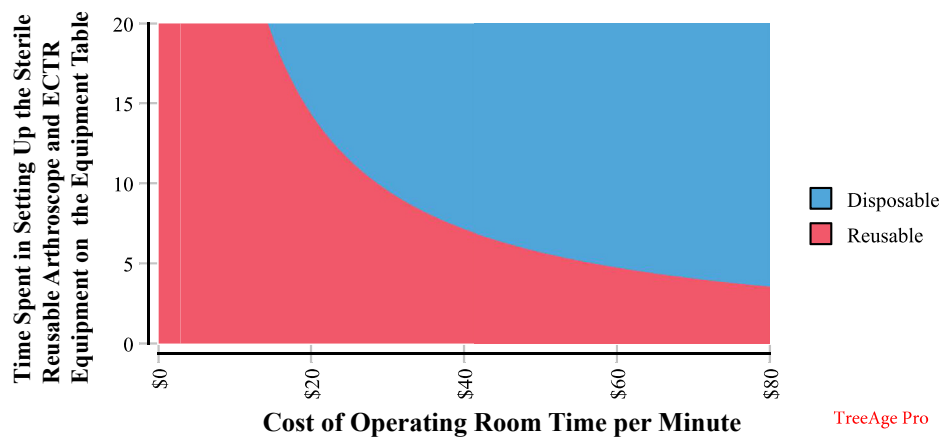


FIGURE 8: Two-way sensitivity analysis (with all other variables held constant) shows that at lower cost per minute of operating room time (ie, <\$18/min) setup of reusable equipment in the operating room can exceed 20 minutes and still be the less-expensive option (red shading). At higher costs per minute for operating room time (eg, >\$40/min), operating room setup time needs to be accelerated (eg, <7 min) in order for the reusable option to still be the less-expensive option.

ECTR equipment in carpal tunnel release procedures, if the choice for surgery is endoscopic. Further study is warranted to demonstrate whether this cost savings is concordant with improvements in patient outcomes, environmental impacts, and patient safety.

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Sensitivity Analysis

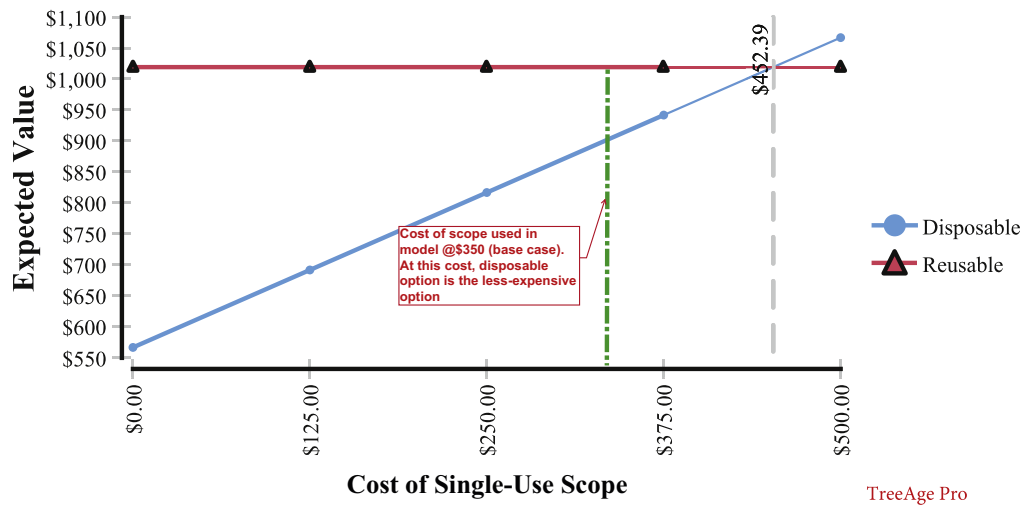


FIGURE E1: Cost of single-use scope.

Sensitivity Analysis

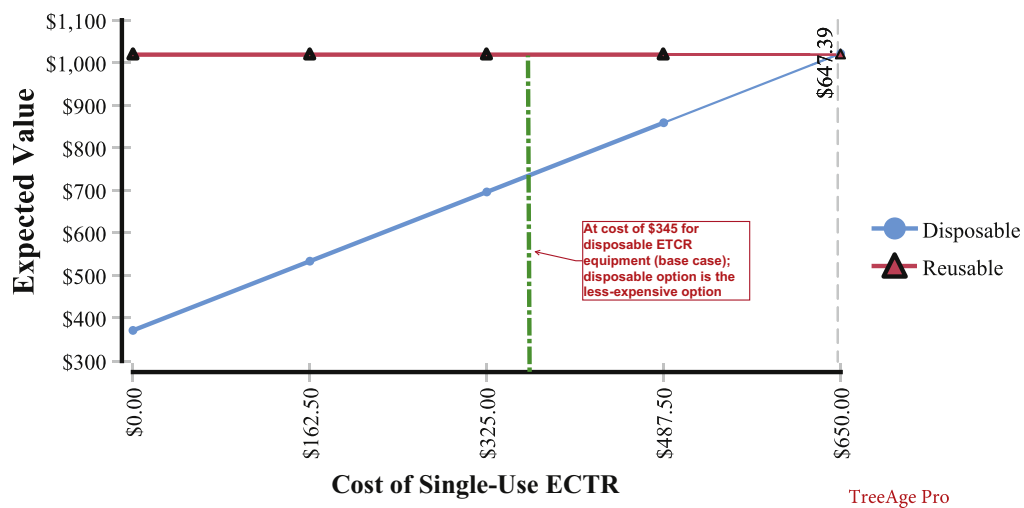


FIGURE E2: Cost of single-use ECTR.

Sensitivity Analysis

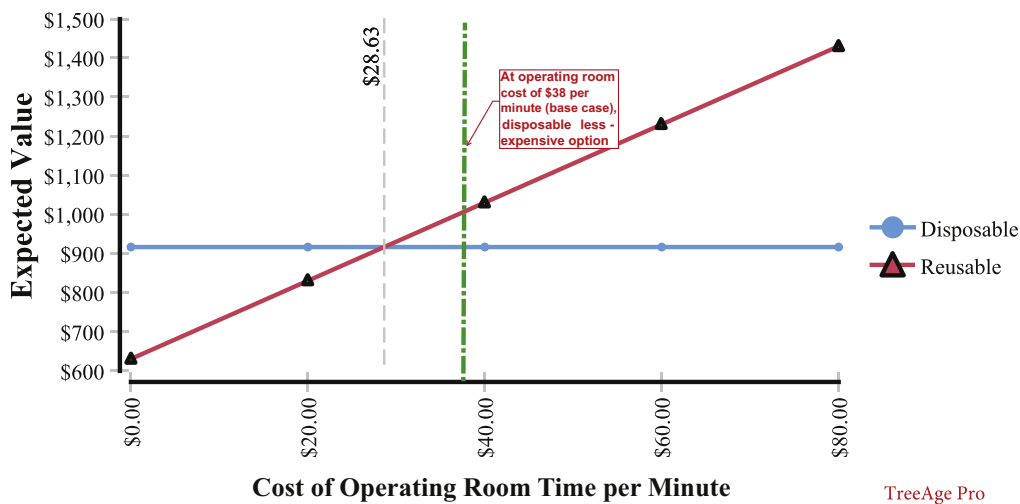


FIGURE E3: Cost of operating room time in minutes.

Sensitivity Analysis

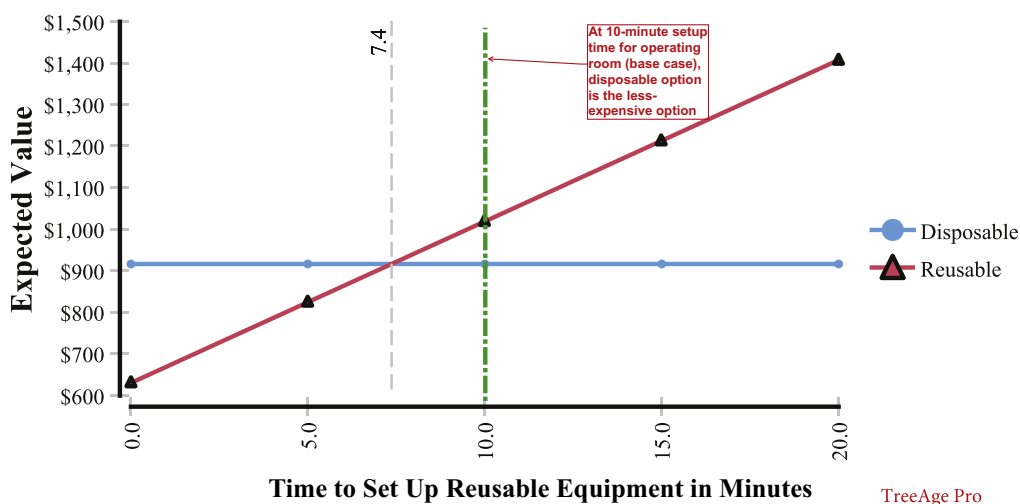


FIGURE E4: Time to set up reusable equipment in minutes.

Sensitivity Analysis

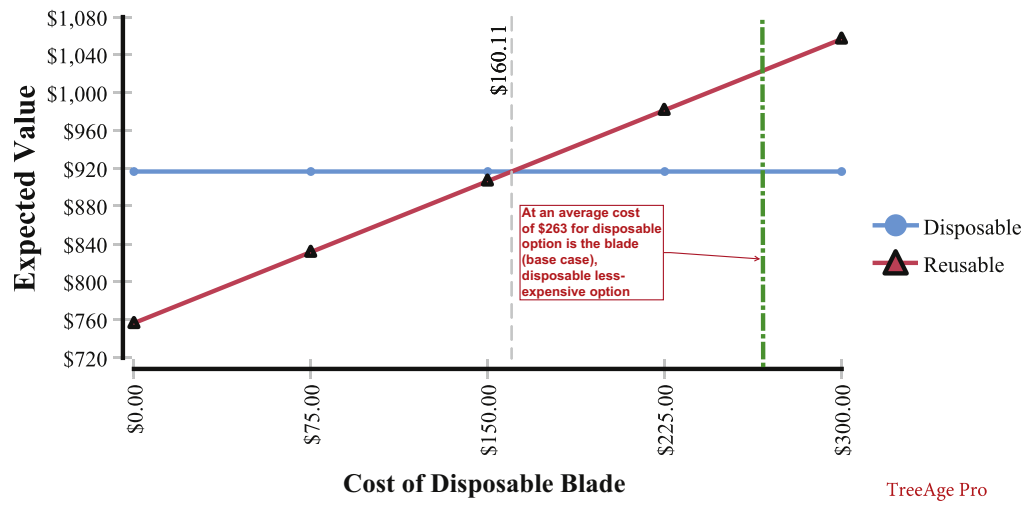


FIGURE E5: Cost of disposable blade.

APPENDIX A. Variables Used in Analysis

Name	Description	Formula	Value	Low	High	Comment
Backup_reusable_scope	Cost of backup scope on a per-use basis.	21.86	\$21.86	\$0.00	\$21.86	Estimation of \$4,700 purchase price; assumes a lifespan of 43 mo with 5 uses per mo. $\$4,700/215 = \21.86
Cost_disposable_blade	Cost of a disposable blade used with reusable equipment	Disposable blade	\$262.50	\$0.00	\$300.00	Estimate from Microaire
Cost_OR_time_minute	Cost of operating room time per min	Cost per minute of operating room time	\$38.86	\$0.00	\$80.00	Use of several inputs into cost of operating room time included in distributions
Cost_single_use_ECTR	Cost of disposable ECTR equipment	545	\$545.00	\$0.00	\$1,000.00	Trice Medical
Cost_single_use_scope	Cost of single-use scope for ECTR	350	\$350.00	\$0.00	\$500.00	Per Trice Medical—list price
Cost_SSI_reusable	Cost of surgical site infection (SSI) directly related to reusable equipment	Cost of SSI	\$17,994.50	\$0.00	\$20,000.00	Source: Stone PW. Economic burden of healthcare-associated infections: an American perspective. <i>Expert Rev Pharmacoecon Outcomes Res.</i> 2009; 9(5):417–422
Costs_drying_store		Costs of drying and storage	\$3.05	\$0.00	\$3.05	Per ANSI ST91 2015 requirements; International Association Healthcare Central Service Material Management 2017 (Table 5)
Costs_manual_clean		Costs of manual cleaning and/or presterilization	\$24.12	\$0.00	\$24.12	Per ANSI ST91 2015 requirements; International Association Healthcare Central Service Material Management 2017 (Table 5)
ECTR_capital equip_ use_per_case	Use of ECTR capital equipment on a per-use basis	18.54	\$18.54	\$0.00	\$20.00	Assumes cost of ECTR of \$3,995 and a lifespan of 43 mo with 5 uses per mo or 215 total uses. $\$2000/215 = \$9.30/\text{use}$
High_level_disinfect		High-level disinfection	\$13.98	\$0.00	\$13.98	Per ANSI ST91 2015 requirements; International Association Healthcare Central Service Material Management 2017 (Table 5)
Labor_costs_paperwork_repairs	Labor costs associated with paperwork in sending out a scope for repairs	10.60	\$10.60	\$0.00	\$10.60	International Association Healthcare Central Service Material Management 2017; assumes 20 min of paperwork associated with sending an endoscope out for repair; assumes central service technician at \$31.80/h

(Continued)

APPENDIX A. Variables Used in Analysis (Continued)

Name	Description	Formula	Value	Low	High	Comment
Labor_reprocessing_sterilization		Labor reprocessing activities	\$32.25	\$0.00	\$32.25	Per ANSI ST91 2015 requirements; International Association Healthcare Central Service Material Management 2017 (Table 5)
Personnel_costs_drying_storing	Personnel costs for drying and storing equipment	1.12	\$1.12	\$0.00	\$1.12	Per ANSI ST91 2015 requirements; International Association Healthcare Central Service Material Management 2017 (Table 14)
Preclean_verification		Precleaning verification presterilization	\$32.16	\$0.00	\$32.16	Per ANSI ST91 2015 requirements; International Association Healthcare Central Service Material Management 2017 (Table 5)
Precleaning_transport		Costs of precleaning transport	\$11.80	\$0.00	\$11.80	Per ANSI ST91 2015 requirements; International Association Healthcare Central Service Material Management 2017 (Table 5)
Preoperative_setup_costs	Preoperative set up costs of operating room	8.35	\$8.35	\$0.00	\$8.35	Per Koehler et al, 2019 ⁸ : amount of time for setup and opening of reusable and sterile surgical supplies is 5 minutes (Fig. 1). Assume a surgical technologist sets up sterile equipment at a rate of \$0.64/min and a circulating nurse is present at \$1.03/min (Table 2) = \$1.67/min
Preprocessing_materials_prior_sterilization		Preprocessing materials	\$11.42	\$0.00	\$11.42	Per ANSI ST91 2015 requirements; International Association Healthcare Central Service Material Management 2017 (Table 5)
Refurbishment_costs	Refurbishment costs	16.57	\$16.57	\$0.00	\$16.57	Cost of refurbishments \$940/ use. Number of refurbishments = 3.8. Total cost of refurbishments = \$3,570; number of uses = 215.5
Repair_costs	Costs for repairing arthroscope	20.09	\$20.09	\$0.00	\$20.09	Estimate from Millennium Research Group. Reusable rigid endoscopic cost analysis. 2006 (presentation). Average repair costs \$4,330 over 215.5 uses
Reusable_arthroscope	Cost of arthroscope on a per-use basis	21.86	\$21.86	\$0.00	\$21.86	Estimation of \$4,700 purchase price; assumes a lifespan of 43 mo with 5 uses per mo. \$4,700/ 215 = \$21.86
Risk_SSI	Risk of an SSI	Risk of infection from reusable equipment	0.50%	0.00%	2.00%	Derived from Rutula WA et al. Guideline from disinfection and sterilization in healthcare facilities, 2008. Available at: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/ Accessed July 19, 2019

(Continued)

APPENDIX A. Variables Used in Analysis (Continued)

Name	Description	Formula	Value	Low	High	Comment
Sterilization_costs_reusable_ECTR	Sterilization costs for ECTR equipment	30.39	\$30.39	\$0.00	\$30.39	Per Koehler et al, 2019 ⁸ : amount of time for sterilization is 57 min. Assume a central sterilization employee is paid at a rate of \$0.53/min. Total cost is \$30.39 (Table 2)
Time_setup_reusable_equipment	Time spent in setting up sterile reusable arthroscope and ECTR equipment on equipment table	Set up time of ECTR reusable equipent	10	0	20	See distributions

APPENDIX B. Equations Used in Model

Arm	Equations	Result
Disposable	$\text{Cost_single_use_ECTR} + \text{Cost_single_use_scope} + \text{Backup_reusable_scope}$	\$916.86
Reusable	$\text{ECTR_Capital_Equip_Use_Per_Case} + \text{Cost_disposable_blade} + \text{Reusable_arthroscope} + \text{Backup_reusable_scope} + \text{Preprocessing_materials_prior_sterilization} + \text{Precleaning_transport} + \text{Costs_manual_clean} + \text{Preclean_verification} + \text{High_level_disinfect} + \text{Costs_drying_store} + \text{Repair_costs} + \text{Refurbishment_costs} + \text{Labor_reprocessing_sterilization} + \text{Sterilization_costs_reusable_ECTR} + \text{Personnel_costs_drying_storing} + \text{Preoperative_setup_costs} + \text{Labor_costs_paperwork_repairs} + \text{Cost_OR_Time_minute} * \text{Time_setup_reusable_equipment} + \text{Risk_SSI} * \text{Cost_SSI_reusable}$	\$1,019.25