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Simultaneous Bilateral Versus Staged Bilateral Carpal Tunnel Release: A Cost-effectiveness Analysis

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Abstract

The purpose of this study was to determine if simultaneous bilateral carpal tunnel release (CTR) is a cost-effective strategy compared with bilateral staged CTR for the treatment of bilateral carpal tunnel syndrome.

Methods—A decision analytic model was created to compare the cost effectiveness of three strategies (ie, bilateral simultaneous CTR, bilateral staged CTR, and no treatment). Direct medical costs were estimated from 2013 Medicare reimbursement rates and wholesale drug costs in US dollars. Indirect costs were derived from consecutive patients undergoing unilateral or simultaneous bilateral CTR at our institution and from national average wages for 2013. Health state utility values were derived from a general population of volunteers using the Short Form-6 dimensions (SF-6D) health questionnaire.

Results—Both surgical strategies were cost effective compared with the no-treatment strategy. Bilateral simultaneous CTR had lower total costs and higher total effectiveness than bilateral staged CTR, and had an incremental cost-effectiveness ratio of \$921 per quality-adjusted life year compared with the no-treatment strategy. The conclusions of the analysis remained unchanged though all sensitivity analyses, displaying robustness against parameter uncertainty.

Conclusions—Surgical management is cost effective for the treatment of bilateral carpal tunnel syndrome. Bilateral simultaneous CTR, however, has lower total costs and higher total effectiveness compared with bilateral staged CTR.

Level of Evidence—Economic and Decision Analysis I

Keywords

carpal tunnel; bilateral carpal tunnel; CTR; economic decision making; cost analysis; CEA

Carpal tunnel syndrome (CTS) is the most common compressive neuropathy in the upper extremity, with a prevalence of 3% to 5% in the general population and 8% in the working population.^{1,2} Carpal tunnel release (CTR) is the most common ambulatory upper extremity

surgery performed in the United States. In 2006, 577,000 CTRs were performed, a 38% increase from a decade earlier.³

CTS leads to a loss in worker productivity. In 2012, the Bureau of Labor Statistics reported that patients with CTS missed a median of 30 days of work, comparable to the number of work days missed as a result of a fracture.⁴ This missed work time and decreased productivity represent an economic burden to both patients and the economy.⁵ The overall cost of CTS is estimated at \$2 billion annually in the United States.⁶

In patients with CTS, 60% to 70% experience bilateral symptoms.⁷ Given the high rate of symptomatic bilateral CTS, simultaneous bilateral CTR is a surgical option that may decrease both healthcare spending and the loss in worker productivity. Previous studies have shown a more rapid return to work and a lower total cost of surgery in patients who undergo simultaneous bilateral release.^{8,9}

As we face rising healthcare costs, it is becoming increasingly important to optimize the allocation of finite medical resources. Doing this can be facilitated by cost-effectiveness analyses that serve to integrate patient preferences with treatment outcomes, complications, and costs. The purpose of this study was to compare the cost effectiveness of bilateral staged and bilateral simultaneous CTR for the treatment of bilateral CTS.

Methods

Study Design

We conducted a cost-effectiveness analysis following the recommendations of the Panel on Cost-Effectiveness in Health and Medicine.¹⁰ The target population consisted of patients with clinically diagnosed and electrodiagnostically confirmed bilateral CTS who failed to respond to nonsurgical management and therefore were recommended to undergo surgical management. Average patient age and life expectancy were assumed to be 40 years and 80 years, respectively.¹¹

Patients were distributed into three groups: bilateral simultaneous CTR, bilateral staged CTR, and no treatment (Figure 1). The no-treatment group was included as a modeling reference point against which the incremental cost effectiveness of the simultaneous and staged CTR strategies could be compared. The bilateral simultaneous group had a CTR performed on both hands during the same operation. The bilateral staged group received a CTR on one hand; either a second CTR was performed on the other hand 6 weeks later or the second surgery was canceled. The no-treatment group did not undergo surgery and remained symptomatic.

Each surgery was followed by a postoperative recovery period of 4 months and an outcome of either no complication or with complication (ie, persistent symptoms, pillar pain, wound infection, and median nerve injury). Outcome probabilities for each of the bilateral surgeries were independent of one another. The health state utility after postoperative recovery with either no complications or temporary complications returned to a baseline health utility.

TreeAge software (TreeAge Pro Suite, Version 2013; TreeAge Software) was used to perform the analysis.

Perspective

The societal perspective was adopted for this analysis. It is the most appropriate choice because it represents the viewpoint of society as a whole rather than that of any particular group.¹⁰

Health States and Probabilities

A review of MEDLINE from January 1980 to December 2013 was conducted to identify prospective and/or randomized controlled trials that included open CTR as one of its treatment options. A total of 27 studies was identified, of which 11 either did not report complication rates or reported no complications. From the remaining 16 studies, the 4 most representative complications were selected: persistent symptoms, pillar pain, wound infection, and nerve injury.^{12–27} Probabilities for each outcome were calculated by weighted averages (Tables 1 through 3). The cancellation rate of the second surgery for the bilateral staged group was estimated from a large, retrospective study.²⁸

Utilities

Utility values reflect the preference placed on a particular health state and range from 0.0 (death) to 1.0 (perfect health). Utility values are used to calculate quality-adjusted life years (QALY = $\sum_i [\text{utility value of health state}_i] \times [\text{time spent in health state}_i]$), which provide a single index number to measure both life years and quality of life.^{29,30} This allows for the comparison of effectiveness among a wide range of different diseases and treatment options, facilitating the cost-effective allocation of limited healthcare resources.

For the societal perspective, health state utility values were elicited from a general population using the Short Form-6 dimensions (SF-6D) survey, a preference-based health questionnaire validated for CTS.^{31,32} After approval from the Institutional Review Board, we recruited prospective subjects from among the friends and family members who accompanied patients to the orthopaedic hand clinic. Consenting participants were presented with scenarios that included a descriptive vignette (see the online Appendix), followed by the SF-6D survey. The vignettes consisted of a detailed description of each of the health states before and after CT surgery in terms of symptoms and physical limitations, and the ordering was randomized to minimize anchoring bias. To avoid any double counting of opportunity costs, participants were explicitly instructed to assume that their financial circumstances would not be affected (eg, they did not have to pay for health care and any lost earnings would be replaced with disability payments) because these costs were incorporated into the calculation of indirect costs.³³

All utility values were determined for a unilateral state, and associated disutilities were assumed to be additive. The utility value of the persistent symptom state was assumed to equal that of the unilateral CTS state. Participants in the staged strategy in which the second surgery was canceled were assumed to continue to have CTS in the nonoperated hand throughout the duration of their lives.

Cost

Both direct and indirect costs were included in our analysis. Direct medical costs (eg, the net expenditure of healthcare resources) were estimated by Medicare reimbursement rates and wholesale drug costs in US dollars. Medicare reimbursement rates were calculated for 2013 using the geographic practice cost index for metropolitan St. Louis, Missouri (cms.gov/Medicare/Medicare.html). Costs for surgery included physician, anesthesia, and facility fees. CTR has a “bilateral surgery” indicator of “1” and, thus, 150% payment adjustments for bilateral CTR were made for physician and facility fees. Anesthesia fees were calculated assuming a 30-minute surgical time for unilateral CTR, 45 minutes for bilateral CTR, and 120 minutes for median nerve grafting. The cost of treating a wound infection was estimated using wholesale drug costs for a 10-day course of generic cephalexin.

Indirect costs include the opportunity cost for the time spent receiving medical care and, when not included in the measure of effectiveness, the lost income and productivity resulting from sick leave. These costs were calculated using average wages reported by the Bureau of Labor Statistics for 2013.³⁴ CT surgery was estimated to require 1 work day. We were unable to identify a previously reported reliable estimate of days missed from work. Therefore, additional missed days from work were calculated by performing a prospective assessment of consecutive patients with bilateral CTS and indicated for CTR bilaterally. After approval from the Institutional Review Board, consenting patients were offered the choice of simultaneous or staged CTR. Work absence after the index surgery was determined using the validated World Health Organization Health Performance Questionnaire.³⁵ For modeling purposes, the total number of missed days following staged CTR was assumed to be twice that of the index surgery. Because of the relatively brief time horizon of 6 months, no discounting was employed.

Outcome Measure

The incremental cost-effectiveness ratio (ICER) between a treatment strategy and its alternative is calculated by dividing the difference in cost by the difference in effectiveness to obtain a ratio in cost/QALY. This ratio reflects the cost incurred for each additional unit of effectiveness offered by the alternative treatment strategy. A trade-off exists between two strategies if one treatment costs more but is also more effective than the alternative. Conversely, a treatment strategy is dominated if it costs more and is less effective.

Sensitivity Analysis

To assess the robustness of our conclusions, we conducted five separate sensitivity analyses. First, we analyzed the model using only direct medical costs by removing the indirect costs (eg, opportunity costs for seeking medical care, lost work time). Second, we analyzed the model using (mean utility values + standard error [SE]) and again with (mean utility values – SE). Third, we varied the bilateral simultaneous postoperative recovery time between 4 to 12 months. Fourth, we analyzed the model assuming a 0% cancellation rate for the second surgery of the bilateral staged group. Finally, we conducted a post hoc threshold analysis to determine the number of additional missed work days that must be associated with the simultaneous strategy for it to no longer be dominant over the staged strategy.

Results

Utilities, Probabilities, and Cost

A total of 50 participants completed the surveys to measure the utility values of the six different health states. Demographic information is summarized in Table 4. SF-6D scores were translated into utility values using the US valuation of the SF-6D, and average utilities were obtained for each health state.³² A total of 42 patients, including 21 patients who underwent simultaneous CTR and 21 patients who underwent staged CTR, completed the World Health Organization Health Performance Questionnaire, with average missed work days of 9.3 (SD = 3.7) and 9.2 (SD = 2.2), respectively (Table 5).

All the parameters used in the model (cost estimates, surgical outcome and cancellation rate probabilities, and health state utilities) are presented in Table 6.

Incremental Cost-effectiveness Ratio

In the reference case, both the bilateral simultaneous and bilateral staged strategies had higher total costs and higher total effectiveness compared with the no treatment option. Compared with receiving no treatment, both the simultaneous strategy (ICER \$921 per additional QALY) and staged strategy (\$1,727 per additional QALY) were cost-effective treatments of bilateral carpal tunnel. However, a direct comparison of the simultaneous and staged strategies determined that the staged strategy was dominated by the simultaneous strategy; the staged strategy had higher total costs (\$4,119 versus \$3,033) and lower total effectiveness (37.172 versus 38.091 QALYs; Table 6).

Sensitivity Analysis

Results from the sensitivity analyses are summarized in Figure 2. Incremental cost effectiveness is reported for simultaneous and staged strategies relative to no treatment. When the simultaneous and staged CTR strategies were compared directly, the simultaneous strategy persistently dominated the staged strategy; thus, an ICER could not be calculated. With consideration of direct medical costs only, the total costs were \$1,900 for simultaneous and \$2,201 for staged strategies. The total effectiveness was not affected; thus, the staged strategy remained dominated because it had higher total costs and lower total effectiveness. Variation of the utility values did not change the total cost for any strategy. QALYs, however, decreased to 37.584, 36.571, and 34.000 with (mean utility values – SE) for simultaneous, staged, and no treatment, respectively, and increased to 38.599, 37.773, and 35.600 with (mean utility values + SE) for simultaneous, staged, and no treatment, respectively. The simultaneous strategy remained dominant over the staged strategy. When the postoperative recovery period following bilateral simultaneous CTR was increased to 12 months, the total effectiveness decreased to 38.050 QALYs but remained greater than that of the staged strategy. With a 0% cancellation rate for the second surgery in the bilateral staged group, total costs increased to \$4,819, and total effectiveness increased to 38.088 QALYs. The staged strategy, however, persistently had higher total costs and lower total effectiveness than that of the simultaneous strategy. The threshold analysis for the number of missed work days associated with the simultaneous CTR strategy revealed that the simultaneous CTR

remained dominant until a patient missed an additional 10 days more than he or she would have following staged CTR.

Discussion

CTS has been shown to be a bilateral disorder with the eventual development of CTS in both hands in approximately 70% of all affected patients.⁷ When treating bilateral CTS, many surgeons are reluctant to perform bilateral simultaneous CTR, believing that the postoperative morbidity interferes with proper personal care and return to work.⁸ However, recent studies have shown that bilateral simultaneous CTR is well tolerated by patients and is also associated with lower total costs compared with staged releases.^{8,24–26}

To our knowledge, this study is the first full economic analysis that examines the cost effectiveness of staged and simultaneous CTR for the treatment of bilateral CTS. In the reference case, the simultaneous strategy was dominant over the staged strategy because it had lower total costs and higher effectiveness. Indirect costs were a large component of total costs, contributing 37% and 47% of total costs of the simultaneous and staged strategies, respectively. Despite the large contribution of indirect costs, a sensitivity analysis revealed that the absence of these costs had no effect on the results. Furthermore, the simultaneous strategy remained dominant over the staged strategy through all the sensitivity analyses, proving to be robust against variance in utility values, postoperative recovery time, and second-surgery cancellation rates.

Findings from this study are consistent with those of previously published studies that have compared either the costs or the outcomes of these two strategies.^{8,24,25} The staged strategy has consistently incurred higher costs attributable to higher surgical fees, more clinic visits, and more time off work. Average reimbursement rates reported by Elfar et al³⁶ were in accord with the Medicare reimbursement rates estimated in this analysis (ie, \$1,864 versus \$1,893 for simultaneous and \$2,897 versus \$2,568 for staged). For clinic visits, previous studies have reported more visits with bilateral staged releases. Our model, however, was relatively conservative and assumed an equal number of clinic visits because an assumption of additional visits for patients who elect to undergo staged procedures would increase the incremental cost of staged surgery and would not alter the conclusions of the analysis. We chose a relatively short interval of 6 weeks between staged procedures to minimize the total length of time that a patient with staged procedures experienced the disutility associated with recovery from surgery. The choice of a longer interval between staged surgeries would have led to a further decrease in the effectiveness of staged surgeries. The number of postoperative missed work days measured from our patient population exhibited a similar trend but was consistently fewer than in other studies, which averaged 3 weeks for simultaneous and 6 weeks for staged releases.^{8,36} Again, this reflects the conservative nature of our model, and using the values reported by other studies would increase the incremental cost of staged surgery.

Despite the reasonable belief that bilateral simultaneous release would result in greater postoperative morbidity compared with bilateral staged release, patients have been shown to respond well to simultaneous release. No differences were found in terms of morbidity,

activities of daily living, or abilities for one-handed or two-handed activities between simultaneous and staged releases during postoperative recovery.^{8,24} In addition, patients from both groups expressed comparable satisfaction rates and a willingness to repeat the same treatment strategy.^{25,26} This similarity in postoperative recovery was reflected in our reference case but was tested in a sensitivity analysis. The conclusions were resistant to increased bilateral simultaneous postoperative morbidity, and simultaneous release remained dominant even when its postoperative recovery period was extended to three times that of staged release. From a modeling perspective, this is also equivalent to a threefold increase in disutility during the recovery period following simultaneous surgery, assuming an equal postoperative recovery time period between the two strategies. Additionally, the staged strategy was dominated until 10 additional missed work days were associated with the simultaneous strategy. Although we cannot rule out the possibility that some subpopulations of patients might miss twice as many days following a single surgery than they would have after two staged surgeries, the finding is reflective neither of the evidence on return-to-work outcomes in previous studies nor the findings in this study.^{8,24,36}

Several potential limitations exist in this cost-effectiveness analysis. As with any decision analytic model, this analysis was based on several assumptions and estimations. These uncertainties, however, can be minimized by using the most accurate data obtained from validated measures and randomized controlled trials. Uncertainties of the probabilities of surgical outcomes were minimized by using the weighted averages among a large pool of randomized controlled trials. Furthermore, the dominance of the simultaneous strategy over the staged strategy prevented a direct calculation of the incremental cost-effectiveness ratio between the two strategies. As a result, we included no treatment as a clinically relevant reference point in our decision analysis. This decision strengthened the reported findings in two ways: (1) by allowing the study to be conducted in keeping with the recommendations of the Panel on Cost-Effectiveness in Health and Medicine, and (2) by allowing the study to answer the clinically relevant question, “If patients with bilateral CTS have the choices of simultaneous or staged CTR for surgical treatment, how costly is each treatment and how much benefit will they derive from their decision relative to their current health state?”

Costs were estimated using Medicare reimbursement rates as well as work productivity data from patients at our institution. Medicare reimbursement rates are significantly lower than reported averages and thus may not reflect the true economic burden to society.²⁹ This shortcoming, however, is offset by its standardization, which allows for reproducible estimations as well as valid comparability to a wide range of other economic analyses. Regarding indirect costs, return to work following CTR is influenced by occupation, expectations, anxiety, and other factors and, thus, can be highly variable.³⁶ This variability may affect the generalizability of the findings from this study; however, any effects are likely minimal because a sensitivity analysis showed that exclusion of indirect costs does not affect the results.

Health state utility values were estimated using a general population, descriptive vignettes, and the validated SF-6D health questionnaire. The Panel on Cost-Effectiveness in Health and Medicine recommends the elicitation of utility values from a general population because it is in accord with the societal perspective.¹⁰ General population utility value estimates,

however, are reported to differ from those of affected patients.³⁷ This can, at least partially, be explained by the general population's poor understanding of the actual impact a particular health state has on one's life. Previous cost-effectiveness analyses using a general population for utility value estimation have employed descriptive vignettes and direct utility measurements, such as time trade-off or standard gamble.^{38,39} In contrast, the SF-6D health questionnaire, validated for CTS, was used in this study to assist in the general population's evaluation of the health states. The SF-6D provides discrete, explicit dimensions (ie, physical functioning, role limitations, social functioning, pain, mental health, vitality) that may encourage participants to consider the impact of a specific health state in a more systematic and thorough approach. Additionally, it was well received by our participants and may reduce the cognitive burden commonly associated with direct utility measures.⁴⁰

This cost-effectiveness analysis serves to provide objective clinical practice recommendations for the treatment of bilateral CTS. Simultaneous CTR has lower total costs and higher total effectiveness than does staged CTR. Both simultaneous and staged CTR, however, are cost-effective treatment strategies, confirming the overall value of surgical intervention in patients with symptomatic bilateral CTS. Although these findings are informative, individual patient circumstances and preferences should dictate which treatment option best supports a patient's well-being and quality of life.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Dr. Boyer or an immediate family member serves as a board member, owner, officer, or committee member of the American Society for Surgery of the Hand. Dr. Gelberman or an immediate family member has received royalties from Medartis and serves as a board member, owner, officer, or committee member of the American Foundation for Surgery of the Hand, the American Society for Surgery of the Hand, and the American Orthopaedic Association. Dr. Calfee or an immediate family member serves as a paid consultant to DePuy Synthes, has received research or institutional support from Medartis, and serves as a board member, owner, officer, or committee member of the American Society for Surgery of the Hand. Dr. Osei or an immediate family member serves as a board member, owner, officer, or committee member of the American Society for Surgery of the Hand. Neither of the following authors nor any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Park and Dr. Stepan.

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References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references ^{13–15}, ¹⁷, ²⁰, and ²⁷ are level I studies. References ^{1–3}, ¹⁶, ¹⁹, ²³, ²⁵, ²⁶, ³⁷, and ³⁸ are level II studies. References ^{7–9}, ¹², ²⁸, ³⁶, ³⁹, and ⁴⁰ are level III studies. Reference ⁶ is a level IV study. References ¹⁰ and ^{29–33} are level V expert opinion.

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Figure 1.

Decision tree and cost-effectiveness model for patient with symptomatic bilateral carpal tunnel syndrome.

Figure 2.

One-way sensitivity analysis of Incremental Cost-Effectiveness Ratio (cost/quality-adjusted life year) for simultaneous (black bar) or staged (white bar) bilateral carpal tunnel release against direct medical costs, against standard error (SE) of the mean health state utility, against the duration of the postoperative recovery period (4 months versus 8 months versus 12 months), and against a 0% cancellation rate for staged bilateral carpal tunnel release.

Table 1

Variable Parameters for Costs

Procedure	Direct Costs			Indirect Costs		CPT Codes	
	Surgeon	Anesthesia	Facility Fees ASC	Time (d)	Opportunity Cost	Surgery	Anesthesia
Unilateral CTR	\$427	\$110	\$747	1 + 9.2	\$1,122	64721	01710
Bilateral CTR	\$641	\$132	\$1,120	1 + 9.3	\$1,133	64721	01710
Median nerve grafting	\$814	\$592	\$1,431	—	—	64835	01710

ASC = ambulatory surgical center, CPT = Current Procedural Terminology, CTR = carpal tunnel release

Table 2

Variable Parameters for Probabilities

Probabilities ^{12–27}	Weighted Average (range)
Persistent symptoms	0.12 (0.01 to 0.43)
Pillar pain	0.13 (0.02 to 0.30)
Wound infection	0.04 (0.01 to 0.06)
Nerve injury	0.001
Cancellation of second surgery	0.29

Table 3

Variable Parameters for Utility Values

Utility Values	Utility ($\pm$ SE)	Duration
Baseline	0.98 ($\pm$ 0.01)	—
Carpal tunnel syndrome	0.87 ($\pm$ 0.02)	—
Recovery without complications	0.92 ($\pm$ 0.02)	4 mo
Pillar pain	0.81 ($\pm$ 0.04)	3 wk
Wound infection	0.79 ($\pm$ 0.05)	3 wk
Median nerve injury	0.74 ($\pm$ 0.03)	12 mo

SE = standard error

Table 4

Demographic Characteristics of Survey Respondents

Characteristic	N
Sex	
M	24 (48%)
F	26 (52%)
Age (mean $\pm$ SD)	41 yr ($\pm$ 14 yr)
BMI (mean $\pm$ SD)	24.7 ($\pm$ 3.9)
Race	
Caucasian	30 (60%)
Black	14 (28%)
Asian	3 (6%)
Native	0 (0%)
Hispanic	3 (6%)
Other	0 (0%)
Marital Status	
Married	31 (62%)
Separated	1 (2%)
Divorced	5 (10%)
Widowed	2 (4%)
Never married	11 (22%)
Education	
High school graduate or GED	5 (10%)
Some college or 2-year degree	11 (22%)
4-year college graduate	28 (56%)
More than 4-year college degree	6 (12%)
Currently employed	34 (68%)
Income	
<\$10,000	0 (0%)
\$10,000 to \$25,000	2 (6%)
\$25,000 to \$50,000	17 (50%)
\$50,000 to \$75,000	9 (26%)
\$75,000 to \$100,000	3 (9%)
>\$100,000	3 (9%)

SD = standard deviation

Table 5

Characteristics of Patients With Bilateral Carpal Tunnel Syndrome Following Unilateral or Bilateral Carpal Tunnel Release

Characteristic	Unilateral (N = 21)	Bilateral (N = 21)
Days of work missed (SD)	9.2 (9.1)	9.3 (10.7)
Age in years (SD)	56.2 (10.7)	52.1 (11.0)
Women (N)	15	13
Profession (N)		
Executive, Administrative, Manager	2	3
Professional	4	3
Technical support	3	3
Sales	2	4
Clerical and administrative support	5	5
Service occupation	3	2
Laborer	2	1

SD = standard deviation

Table 6

Cost, Effectiveness, and Incremental Cost-effectiveness Ratios

Strategy	Total Costs (\$)	Total Effectiveness (QALYs)	Incremental Costs (\$)	Incremental Effectiveness	ICER ^a (Cost/QALY) (\$)
No treatment	0	34.800	—	—	—
Bilateral simultaneous	3,033	38.091	3,033	3.291	921
Bilateral staged	4,119	37.172	4,119	2.372	1,737 ^b

^aIncremental cost-effectiveness ratio (ICER) = (cost of treatment [\$/QALY gained)

^bDominated strategy

QALY = quality-adjusted life year