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Original Research

A Cost-Utility Analysis of Carpal Tunnel Release With Open, Endoscopic, and Ultrasound Guidance Techniques From a Societal Perspective

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A R T I C L E I N F O

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Purpose: The objective of this study was to perform a cost-utility analysis comparing open carpal tunnel release (OCTR), endoscopic carpal tunnel release (ECTR), and carpal tunnel release with ultrasound (CTR-US) guidance. The aim of this study was to determine whether one of the three approaches was dominant from a societal perspective in terms of cost-utility, in order to help inform policy and treatment decision making going forward.
Methods: This study was performed using a decision tree model, with three potential treatment decisions (OCTR, ECTR, and CTR-US). A cost-utility analysis was performed, using the incremental cost-effectiveness ratio. The willingness-to-pay threshold was set at $50,000/quality-adjusted life year (QALY) as per previous literature.
Results: The total payer episode costs for OCTR, ECTR, and CTR-US were $4,324, $4,978, and $3,249, respectively. The cost of time off work for each procedure was $4,376.14, $3,650.24, and $622.20, respectively. The overall QALYs gained from each procedure were 0.42, 0.42, and 0.43, respectively (the maximum possible being 0.5 for a 6-month period). Compared with OCTR, ECTR and CTR-US were both less costly from a societal perspective (−$71.90 and −$4,828.94, respectively) and associated with greater QALYs gained (+0.0004 and +0.0143, respectively).
Conclusions: Overall, the key finding of this study is that, from a societal perspective, CTR-US is less costly and provides greater QALY improvement when compared with OCTR and ECTR, and thus, CTR-US is considered a dominant intervention over both OCTR and ECTR.
Type of study/level of evidence: Economic and decision analysis; IIb.

Compressive neuropathies are a group of conditions that can cause substantial disability and can vary widely in their presentation and treatment courses.[1] Carpal tunnel syndrome (CTS) is the most common of these conditions and occurs when the median nerve is compressed within the carpal tunnel.[2] The presentation includes numbness and tingling in the sensory distribution of the median nerve, as well as weakness and atrophy of the thenar muscles in more severe cases. The risk for CTS is closely linked to repetitive manual work and thus is most common in patients who are of working age.[3] Furthermore, elevated body mass index and activities requiring repetitive hand and wrist movements are risk factors for CTS.[4] The impact of CTS on health-related quality of life has been shown to be similar to chronic diseases such as diabetes and asthma.[5]

Treatments for CTS may initially include nonsurgical modalities, such as bracing, activity modification, and corticosteroid injections.[6] If these treatments do not lead to symptom resolution, carpal tunnel release (CTR) can be performed using a variety of techniques. The most commonly used technique is open CTR (OCTR), in which an incision is made along the palm of the hand, and open decompression of the median nerve is performed.[7]

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Overall, OCTR is associated with high success rates and low complication rates.[8] A “mini-open” approach has also been described and generally uses a palmar incision that is smaller than the traditional OCTR incision, although an exact incision length differentiating OCTR from mini-open CTR has not been defined.[9] For the purposes of this study, OCTR will refer to both traditional OCTR and mini-OCTR. Despite generally positive results overall, incision-related complications can occur with OCTR and may affect recovery, such as scar tenderness and pillar pain.[10] Endoscopic CTR (ECTR) was developed in an effort to reduce the size and length of the incision and accelerate postoperative recovery.[11]

Although some studies show that ECTR is associated with faster recovery, there may be a higher risk of neurologic injury with ECTR.[12,13] Some authors have hypothesized that the risk of neurologic injury during ECTR is due to the limited field of view provided by the endoscopic instruments.[14,15] Thus, CTR with ultrasound (CTR-US) guidance has been developed as an alternative to OCTR and ECTR.[16−23] Carpal tunnel release with ultrasound allows visualization of all critical structures of the wrist while enabling release of the transverse carpal ligament using a small blade and minimizing incision length and invasiveness. Thus, CTR-US may offer the advantage of full visualization while limiting the risk of injury to local structures. As well, CTR-US has been demonstrated in some studies to considerably reduce the length of time required off work.[22,23]

Thus, the objective of this study was to perform a cost-utility analysis comparing OCTR, ECTR, and CTR-US. Our aim was to determine whether one of the three approaches was dominant from a societal perspective in terms of cost-utility, in order to help inform policy and treatment decision making going forward.

Methods

Health economic analysis plan

The analysis plan was developed a priori. This study is reported in accordance with the Consolidated Health Economic Evaluation Reporting Standards 2022 statement.[24]

Study population and comparators

The study population consisted of adults with CTS requiring release. The three techniques compared were OCTR, ECTR, and CTR-US.

Setting and location

Data were obtained from a combination of previous literature, including the highest available level of evidence, where possible.

Perspective

The perspective used in this study was the societal perspective. The societal perspective takes into account direct health care system/payer costs, as well as patient-related factors, such as quality-adjusted life years (QALYs) and time off work.

Time horizon and discount rate

The time horizon was 6 months. According to previous literature, at this stage, the majority of patients have reached a steady state after treatment.[25] Furthermore, the main purported difference between the three evaluated approaches is expected to be in the early recovery phase.[8,12,22,23] As well, although complications can occur beyond this time point, they are less likely to be related to the surgical approach at time points further beyond the surgery.

Selection and measurement of outcomes

The outcomes were measured using a combination of QALYs and time off work. Time off work was quantified by using it to define the length of time from surgery to the time they returned to work. The cost of the time off work period was added to the cost of each pathway according to the length of time spent in the recovery state. This was performed by adding the cost of the median US individual daily income; this represents the cost of replacing an individual's productivity on a societal level given that a person who is off work will need to be replaced during that time, regardless of whether that individual has salary replacement during their time off. The median weekly individual income in Q1 2022 was $1,037 according to the United States Bureau of Labor Statistics.[26]

Measurement and valuation of resources and costs

Cost inputs were calculated based on a combination of International Business Machines MarketScan Research Databases, as well as previous literature comparing the cost-utility of OCTR with ECTR (Table 1).[20] The total episode cost was all costs from a payer perspective including diagnosis, intervention, and rehabilitation costs.

Currency, price date, and conversion

All prices are listed in United States dollars. No conversions were necessary, as all data sources were in United States dollars. All prices were from data collected between 2019 and 2021, and thus, no temporal adjustment was performed based on the price date.

Rationale and description of model

This study was performed using a decision tree model, with three potential treatment decisions (OCTR, ECTR, and CTR-US). Following surgery, each patient was in the “recovery state” (ie, time before returning to work) for the length of time needed to return to work, as per previous literature. For CTR-US and OCTR, this was based on a weighted mean of data from four randomized controlled trials evaluating CTR-US.[22,23,27,28] Time off work for ECTR was based on a recent detailed meta-analysis specifically evaluating return to work following CTR.[29] Following this state, each branch could lead to one of the six end points—full recovery, persistent symptoms, or one of four complications that have had previously reported utility values and likelihoods. Model probability and utility inputs are reported in Tables 2 and 3, respectively. [22,23,27,28,30]

Analytics and assumptions

A cost-utility analysis was performed, using the incremental cost-effectiveness ratio (ICER). The ICER is a ratio of the cost per QALY and can be visualized on an x-y axis with the base case (for our purposes, OCTR) set at the X-Y intercept. The y axis typically represents the difference in cost between the interventions, whereas the x axis represents the difference in QALY among the interventions. Thus, the comparator intervention(s) may be in one of four quadrants, relative to the base case at the x-y intercept (Fig. 1). If the quadrants are labeled in the same way as a map typically would be, the four quadrants would be, in clockwise order, north-east, south-east, south-west, and north-west. An intervention in the south-east quadrant is considered automatically

Table 1
Cost Inputs

Variable	Open CTR	Endoscopic CTR	CTR With Ultrasound Guidance	Notes
Preprocedure costs				Diagnostic ultrasound can be performed in the clinic setting and used to support diagnosis for CTR-US procedures.
EMG*	$1,000	$1,000	$0	
PCP/orthopedic office visit*	$125	$125	$125	
Diagnostic ultrasound*,†	$0	$0	$124	
Subtotal	$1,125	$1,125	$249	
Procedure costs				$3,000 for CTR-US is the bundled case rate in the office. Analysis uses a blended rate of HOPD and ASC utilization for OCTR and ECTR, based on the literature. Carpal tunnel release with ultrasound has no facility fees because of this being in an office setting. Carpal tunnel release with ultrasound procedure allows for return to function without the need of rehab.
Physician fee*	$617	$727	$3,000	
HOPD facility fee*	$2,328	$2,845	$0	
HOPD utilization*	52%	44%	0%	
HOPD cost*	$1,211	$1,252	$0	
Anesthesia*	$235	$235	$0	
PACU*	$400	$400	$0	
ASC facility fee*	$1,239	$1,959	$0	
ASC utilization*	48%	56%	0%	
ASC cost*	$595	$1,097	$0	
Total blended facility cost*	$1,805	$2,349	$0	
Subtotal	$2,657	$3,311	$3,000	
Postprocedure costs				
Rehabilitation, pain management, bracing*	$542	$542	$0	
Payer subtotal	$4,324	$4,978	$3,249	
Mean time off work (d)‡	21.1	17.6	3.0	3 days return to work for CTR-US determined from new publication in press.
Median US weekly income§		$1,037		From Bureau of Labor Statistics
Wage replacement cost subtotal	$4,376.14	$3,650.24	$622.20	
Total cost	$8,700.14	$8,628.24	$3,871.20	Payer costs and wage replacement costs.

ASC, ambulatory surgical center; CTR, carpal tunnel release; HOPD, hospital-based outpatient department; PACU, postanesthetic recovery unit; PCP, primary care provider.
* International Business Machines (IBM) Marketscan and Medicare databases.
† Fowler et al.[20]
‡ Miller et al, unplublished—in press.
§ Bureau of Labor Statistics.

Table 2
Outcome Probability Inputs

Variable	Open CTR	Endoscopic CTR	CTR With Ultrasound Guidance	Source(s)
Persistent symptoms	12.0%	12.0%	1.9%	Barnes et al,[30] Capa-Grasa et al,[22] Rojo-Manaute et al,[23] Eberlin et al,[28] de la Fuente et al[27]
Complex regional pain syndrome	0.30%	0.30%	0.2%	
Pillar pain	15.0%	14.0%	0.2%	
Infection	1.4%	0.5%	0.5%	
Neuropraxia	0.70%	2.0%	1.0%	

CTR, carpal tunnel release.

Table 3
Model Utility Inputs

Variable	Utility	Source(s)
Symptom resolution	0.87	Barnes et al[30]
Recovery state	0.81	
Persistent symptoms	0.81	
Complex regional pain syndrome	0.52	
Pillar pain	0.74	
Infection	0.75	
Neuropraxia	0.71	

“dominant” over the base case, given that it is both cheaper and more effective (ie, higher QALYs). On the other hand, an intervention in the north-west quadrant is automatically inferior to the base case, as it is more costly but less effective. The primary role of the ICER is in helping to decide whether to adopt an intervention that falls in one of the other two quadrants (ie, north-east or south-west), as these are either more costly and more effective (north-east) or less costly but less effective (south-west). The willingness-to-pay threshold was set at $50,000/QALY as per previous literature.[31] Given the short time horizon and acute nature of the procedure, the assumption was made that once an end state was reached, the remaining length of time was spent in that state. Although this may not be true for all the possible complications, it is expected that a majority of the postrecovery time leading up to the 6-month time point would be spent in the management of a complication and that ultimately the end state would have slightly lower utility compared with an uncomplicated, full recovery.

Results

The total payer episode costs for OCTR, ECTR, and CTR-US, were $4,324, $4,978, and $3,249, respectively. The costs of time off work for each procedure were $4,376.14, $3,650.24, and $622.20, respectively. The overall QALYs gained from each procedure were 0.42,

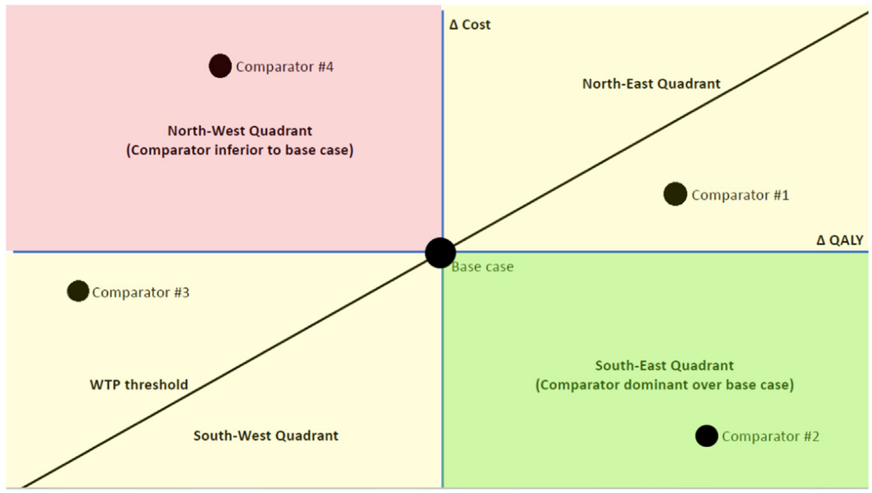

Figure 1. Example ICER quadrant plot. ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life year; WTP, willingness to pay.

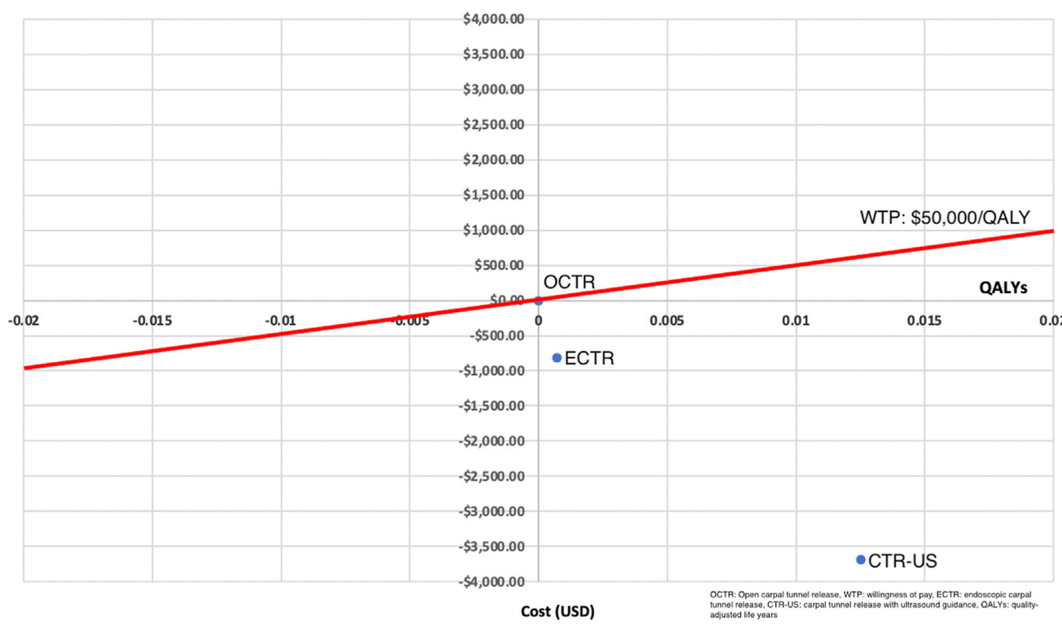

Figure 2. Incremental cost-effectiveness ratio analysis results quadrant plot. CTR, carpal tunnel release; CTR-US, carpal tunnel release with ultrasound; ECTR, endoscopic carpal tunnel release; OCTR, open carpal tunnel release; QALY, quality-adjusted life year; USD, United States Dollar; WTP, wiillingness to pay.

0.42, and 0.43, respectively (the maximum possible being 0.5 for a 6-month period). Compared with OCTR, ECTR and CTR-US were both less costly from a societal perspective (−$71.90 and −$4,828.94, respectively) and associated with greater QALYs gained (+0.0004 and +0.0143, respectively). Thus, both treatments were dominant over OCTR (ie, cheaper and more effective; Fig. 2). The cost of ECTR was only lower than OCTR if the cost of time off work was included in the total cost; otherwise, OCTR had a cheaper total episode cost than ECTR. Carpal tunnel release with ultrasound had a lower cost both in terms of total episode cost and cost of time off work.

In recognition of the relatively smaller number of studies available on CTR-US compared with OCTR and ECTR, and the fact that the estimated rate of persistent symptoms was substantially different between OCTR/ECTR and CTR-US in the model, a post-hoc sensitivity analysis was performed in which the rate of persistent symptoms was set at 12% for all three procedures. Even with this conservative approach, CTR-US still resulted in greater QALYs gained (+0.052 vs OCTR and +0.043 vs ECTR). A sensitivity analysis was also performed without including the cost of wage replacement because of time missed off work; in this analysis, CTR-US was still dominant over OCTR (cost −$1,075), whereas ECTR was associated with a higher cost (+$654) than OCTR.

Discussion

Overall, the key finding of this study is that from a societal perspective, CTR-US is less costly and provides greater QALY improvement when compared with OCTR and ECTR, and thus, CTR-US is considered a dominant intervention over both OCTR and ECTR. Furthermore, ECTR is dominant over OCTR, with marginal gains in QALYs and marginal cost savings.

Our results expand on the previous work of Barnes et al,[30] who compared OCTR and ECTR. The previous study employed an overall similar methodology, although they used a Markov model as opposed to a decision tree in the present manuscript. Similar to the previous study, we found that without incorporating the cost of productivity loss, ECTR is more costly than OCTR, with marginally higher QALYs gained. This is in line with the findings of Barnes et al,[30] and based on our estimates, results in an ICER of $2,574,723.6/QALY gained, which is far higher than any of the well-established willingness-to-pay thresholds. By adding CTR-US as a comparison, our study demonstrates that the potential gains in cost-effectiveness with the adoption of CTR-US may be much more substantial than those from the adoption of ECTR over OCTR, particularly when scaled over the large annual volume of CTR cases performed in the United States, which is estimated at approximately 600,000 cases per year.[32]

Overall, the difference in QALYs between the three approaches was small in magnitude, and all three approaches are associated with successful outcomes and a low risk of complications or adverse events. Again, this is in line with previous economic evaluations of OCTR and ECTR, which have found similar QALYs between the two techniques.[31,33,34] No previous formal economic evaluation studies that included CTR-US were identified. Thus, in the context of marginal differences in QALYs, cost differences play a major role in determining cost-utility. In this regard, the main sources of cost savings in CTR-US procedures came from savings on facility fees and postoperative rehabilitation costs, as well as the reduced time off work.

The length of time off work for each CTR technique is variably reported in the literature. Some studies have demonstrated considerably shorter times off work for CTR-US compared with OCTR, whereas other studies have not found this.[22,23,27,28] Similarly, there is mixed evidence regarding benefits of ECTR compared with OCTR in terms of faster recovery.[8,12,35,36] This heterogeneity in the literature likely stems from a range of sources, including different patient populations and different employment needs (eg, manual/typing labor vs other types of work). Furthermore, with the advent of new technologies, such as voice-to-text, as well as increased flexibility with regard to the ability to work remotely, there is a need for an updated and more detailed evaluation of the impact of each of these techniques on postoperative recovery and return to work.

Strengths of this study include relying on the best available data sources, including a combination of a previous economic analysis, real-world data, and recent randomized controlled trials. In addition, multiple sensitivity analyses allowed us to account for possible variability in real-world results versus published evidence, particularly for the relatively more recently developed procedures. As well, this is one of the first attempts to compare the economic impacts of CTR-US and other CTR approaches from a societal approach.

Limitations include the use of a model-based approach (rather than a trial-based economic analysis). Furthermore, the use of data from multiple different sources and patient populations introduces a certain degree of heterogeneity. A number of assumptions were required to build this model. First, in-office wide awake local anesthesia no tourniquet anesthesia was assumed for CTR-US, which has an impact on cost. This is one of the core-assumed benefits clinically of the CTR-US process. Our clinical experience also has demonstrated that patients do not require rehab or opioids following surgery. The incision is small and in a location that simply requires closure via steri-strips and pain management using ibuprofen. These assumptions are rooted in clinical experience, which is why they were considered reasonable and fair for this model. Another assumption was that recurrence was not considered to be related to surgery after 6 months of follow-up. Carpal tunnel release with ultrasound was designed to allow faster recovery and less invasive access for the procedure, but there is no reason to believe that long-term recurrence would differ between any of the surgical options. Finally, there is a lack of evidence directly comparing CTR-US with ECTR, which means the two approaches are only being compared indirectly through their respective relative costs and effectiveness versus OCTR.

Future directions include further prospective studies with larger sample sizes that directly compare CTR-US with ECTR and OCTR, including trial-based economic evaluations. Furthermore, policy decisions should consider the societal cost-utility of various CTR techniques when determining how funding will be allocated for the treatment of this common and debilitating condition.

Conflicts of Interest

Dr Bhandari reports association or financial involvement with Sonex, Smith and Nephew, BioTraceIT, Bioventus, Ferring, and Acumed. No benefits in any form have been received or will be received by the other authors related directly to this article.

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