Analysis of Expected Costs of Carpal Tunnel Syndrome Treatment Strategies

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Abstract

Background: Over 500 000 carpal tunnel releases costing over \$2 billion are performed each year in the United States. The study's purpose is to perform a cost-minimizing analysis to identify the least costly strategy for carpal tunnel syndrome treatment utilizing existing success rates based on previously reported literature. **Methods:** We evaluate the expected cost of various treatment strategies based on the likelihood of further treatments: (1) a single steroid injection followed by surgical release; (2) up to 2 steroid injections before surgical release; (3) 3 steroid injections before surgery, and (4) immediate surgical release. To reflect costs, we use our institution's billing charges to private payers and reimbursements from Medicare. A range of expected steroid injection success rates are employed based on previously published literature. **Results:** Immediate surgical release is the costliest treatment with an expected cost of \$2149 to \$9927 per patient. For immediate surgical release to cost less than a single injection attempt, the probability of surgery after injection would need to exceed 80% in the Medicare reimbursement model and 87% in the institutional billing model. A single steroid injection with subsequent surgery, if needed, amounts to a direct cost savings of \$359 million annually compared with immediate surgical release. Three injections before surgery, with "high" expected success rates, represent the cost-minimizing scenario. **Conclusions:** Although many factors must be considered when deciding upon treatment for carpal tunnel syndrome, direct payer cost is an important component, and the initial management with steroid injections minimizes these direct payer costs.

Keywords: carpal tunnel syndrome, steroid injection, surgical release, cost, management

Introduction

US health care expenditure continues to grow, accounting for nearly 18% of gross domestic product.⁹ Consequently, both public and private sectors are focusing efforts on containing health care costs across all areas of medicine, including hand surgery. Carpal tunnel syndrome is one of the most commonly treated orthopedic hand conditions, with incident rates in the general population reported at 61 to 120 per 100 000 in women and 35 to 60 per 100 000 in men.⁶ In a recent large survey-based study within the United States, prevalence of clinically diagnosed carpal tunnel syndrome among workers was 6.7%.¹⁷ Over 500 000 carpal tunnel releases are performed each year, with resultant annual costs in excess of \$2 billion.²¹

Despite the prevalence and costs associated with carpal tunnel syndrome, there is no consensus regarding its optimal treatment algorithm.^{2,18,25} The American Academy of Orthopaedic Surgeons (AAOS) Practice Guidelines report strong evidence that use of methylprednisolone injection should improve patient-reported outcomes.¹ The prospective, randomized, double-blinded, placebo-controlled study of

Atroshi et al, comparing steroid injection with placebo, found that patients receiving methylprednisolone were less likely to go on to need surgery, despite no difference in symptom severity scores at 1 year postinjection.³ The true longevity of this nonoperative intervention is controversial, with varying rates, ranging from 67% at 5 years¹² to 19% at 1 year,³ reported in the literature. A recent database study showed a 37% survivorship of up to 2 injections at a median 7.3-year follow-up.¹¹ Similarly, an analysis of national utilization patterns has demonstrated the popularity of not just single but repeat steroid injections as initial management of carpal tunnel syndrome.²⁴ In this study, 29% of patients received an injection as the first line of treatment, and only 40% of patients receiving 1 or more injections underwent subsequent operation.

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Figure 1. Decision analysis tree: treatment options showing potential costs associated with carpal tunnel care.

Note. The square box is the decision node where a choice of treatment is made among 4 possible treatments. Circles are chance nodes at which different outcomes are possible. Depicted here is the “high” probability of success and failure taken from published literature on nationwide utilization data and is represented by the numerical inputs below branches after chance nodes. This analysis was repeated with the “medium” success rates for steroid options 1 and 2, as well as with “low” success rates for steroid option 1. For the purpose of this model, all surgical treatments were considered definitive. cSteroid refers to the cost of steroid injection and cSurg refers to the cost of surgical carpal tunnel release.

The logical pertinent question is the cost-efficiency of this practice, especially because many authors have reported a favorable cost-effectiveness profile of surgical treatment when compared with nonoperative management.¹⁶ If one advantage of surgery is that it reduces costs, and nonoperative management often results in conversion to surgical release, a relevant concern is whether initial and possibly repeat steroid injections are unjustifiably cost prohibitive.

The purpose of this study was therefore to question the ability of repeat injections to minimize cost. In particular, we sought to identify the least costly algorithm for interventional management of carpal tunnel syndrome. In our analyses, we chose to utilize the previously demonstrated payer perspective described by Kerrigan and Stanwix.¹⁵ In a health care system that seeks cost mitigation, and often includes bundled reimbursement plans, an evidence-based cost-minimization strategy for carpal tunnel management may be enlightening.

Materials and Methods

A cost comparison model was employed using decision analysis to compare 4 strategies for the management of carpal tunnel syndrome. DATA (TreeAge Software, Inc, Williamstown, Massachusetts) was utilized to aid in the

analysis. The decision tree (Figure 1) involved a single decision node and was designed with 4 branches for each possible strategy. The 4 strategies were as follows: (1) a steroid injection followed by open surgical release; (2) a steroid injection followed by a second injection before surgical release; (3) 3 steroid injections before surgical release; and (4) immediate surgical release.

Within each strategy, we define success as no need for further treatment, and failure as subsequent injection or surgery. We assume 100% success for surgical intervention. We repeated the decision tree analysis 3 times with different evidence-based probabilities of success, termed “high,” “medium,” and “low” (Table 1). The literature lacks a consensus on the true success rate of steroid injections, with reported reoperation rates ranging from 81% to 33%.^{3,4,7,11,12,27} To capture the unfavorable end of this range, we employed the randomized, placebo-controlled study of Atroshi et al for the “low” success probability analysis of 19%.³ For “high” success rates, we used the previously published nationwide utilization patterns described by Sears et al 2016,²⁴ which provided survivorship data on up to 3 steroid injections prior to surgical intervention. These authors employed the 2009-2013 Truven MarketScan Commercial Claims and Encounters and Medicare Supplement and Coordination of Benefits (MarketScan) databases

Table 1. Selected Variable Steroid Injection Success Rates Adapted From Literature.

Success rate ^a	Author	Year	Country	Journal	Study type	N	Follow-up	Injection survival		
								Single	Second	Third
“High”	Sears et al ²⁴	2016	USA	<i>J Hand Surg Am</i>	Retrospective database	22 934	Mean: 3.3 years, minimum 2 years	63%	56%	53%
“Medium”	Evers et al ¹¹	2017	Sweden	<i>Plast Reconstr Surg</i>	Retrospective database	774	Median: 7.4 years	32%	37%	
“Low”	Atroshi et al ³	2013	USA	<i>Ann Intern Med</i>	Randomized, placebo-controlled trial	37	1 year	19%		

^aEmployed to perform cost-minimizing analysis.

Table 2. Costs Used in the Analysis.

Cost	Injection (dollars) ^a	Surgery (dollars) ^b
Billing charges		
Splint	40	
Professional	300	5000
Technical	792	4927
Total	1232	9927
Medicare reimbursement		
Splint	70	
Professional	90	507
Technical	264	1642
Total	424	2149

^aCurrent Procedural Terminology (CPT) 20526.

^bCPT 64721.

Table 3. Expected Costs of Carpal Tunnel Surgery Treatments.

Treatment	Cost ^a by success probabilities (dollars)		
	“High”	“Medium”	“Low”
Steroid option 1	1219 (4905)	1885 (7982)	2165 (9273)
Steroid option 2	931 (3304)	1632 (6322)	
Steroid option 3	814 (2647)		
Immediate surgery	2149 (9927)	2149 (9927)	2149 (9927)

^aCosts derived from decision tree (Figure 1). Values out of parentheses reflect Medicare reimbursement costs, within parentheses reflect institutional billing costs.

to identify patients with diagnosis of carpal tunnel syndrome initially treated with either steroid injection or surgical release, and then followed them over at least 2 years to determine the need for further intervention. This study reported success rates ranging from 62% to 53% survivorship for the first to third injections. To assess “medium” success rates, we utilized the report of Evers et al,¹¹ who employed Rochester Epidemiology Project medical records linkage system in a database study of corticosteroid injec-

tions for carpal tunnel syndrome. Using this database, the authors reported a 32% survivorship of an initial injection and 37% survivorship of a repeat injection in 774 hands followed over a median of 7.4 years.

Variable costs of surgery and steroid injections were obtained from our medical institution’s billing department (Table 2). These payer costs of surgery include a 90-day global period which includes all follow-up visits, while the injection charges account for only the injection itself. We also included the cost of a single use cock-up wrist splint in the management with steroid injections. Although costs were based on surgeries performed with an anesthesiologist in the operating room, these costs do not include billing or reimbursement for anesthesia or facilities.

Employing these literature-derived probabilities and institutional costs, expected costs were calculated for each strategy and relative costs were compared. We only employed the analysis where probabilities of success were supported by the literature. Thus, because the studies we used to generate “medium” and “low” success rates did not assess a third (medium) or second/third (low) injection, these analyses were not performed. Further assessments were made altering actual costs and probabilities to find break-even parameters at which alternate strategies would be cost minimizing.

Results

The model revealed that steroid injections have a lower expected cost than immediate surgery in all analyzed scenarios except that which employed the “low” injection success rate and Medicare reimbursements (Table 3). For example, in the Medicare reimbursement model, the expected cost of surgery was \$2149, while the expected cost for steroid option 1 (single injection followed by surgery if needed) was \$1219, \$1885, and \$2165 for “high,” “medium,” and “low” success rates. Steroid injections were always less costly from a payer perspective when employing institu-

Figure 2. Cost versus success rate of single injection: graphic representation of expected payer costs of steroid option 1 as a function of steroid injection success rate (-----) compared with cost of immediate surgical release (—).

Note. The expected cost an initial injection followed by surgery if needed dips below the \$2149 cost of surgery at success rates greater than 19.7%. The excess cost of immediate CTR (.....) represents the difference in costs at all probabilities of injection success. Graph depicts calculations based on Medicare reimbursement costs. CTR = carpal tunnel release.

tional billing charges, which widened the cost savings of steroid treatment options compared with immediate surgical release. The least costly outcome was 3 steroid injections in the “high” success rate model, which revealed an expected Medicare cost of \$814. Two steroid injections were less costly than surgery when employing both the “high” and “medium” probabilities of steroid success.

With current Medicare reimbursement of \$2149 for surgical release being approximately 5 times more expensive than the \$424 reimbursement for an injection, in order for immediate surgical treatment to be cost minimizing, the success rate of an injection would have to be less than 19.7% (Figure 2). When employing full institutional billing costs, the steroid success rate would need to drop to 12.4%.

With the “medium” success rate probabilities employed in this study, in order for immediate surgery to have an expected cost less than that of steroid option 1, surgery would have to cost no more than 312% of the cost of an injection or, in the Medicare reimbursement model, just \$1325 dollars, which represents a 38% discount from the current \$2149 cost of surgery. Similarly, for immediate surgery to cost less than 2 attempted injections with expected “medium” success rates, surgery would have to cost just \$1245 or 2.94 times the cost of an injection.

Discussion

Carpal tunnel syndrome is a common diagnosis encountered by the hand surgeon. Despite the economic ramifications of

various treatment options, no optimal algorithm has been defined. Current practice guidelines recommend both steroid injections and surgical release as plausible initial treatment options.¹ Although authors have suggested that a steroid injection reduces the need for further surgery, other studies have advocated for immediate surgical release as a more cost-effective treatment option.^{5,23,26} Regardless, recent literature has shown that nationwide practice varies, as does the reported success rate of steroid injections, and that initial steroid injection may reduce the number of surgical releases eventually performed.^{11,12,24} The purpose of this study is to use the previously described payer perspective to assess the relative costs of different treatment options: either immediate surgical release or up to 3 attempted injections. We attempted to analyze the cost implications for these particular intervention strategies for the treatment of carpal tunnel syndrome.

This study acknowledges several limitations. First, this study employs somewhat arbitrary success rates for its analysis, as there is no consensus within the literature. To account for variations, we employed a range of possibilities. Moreover, a majority of existing studies describing the need for reintervention only assess short-term follow-up periods, which could skew the literature to overestimating the durability of an injection. Thus, for our “medium” and “high” success rates, we utilized database studies with long-term follow-up.^{11,24} Still, the “high” success rate of Sears et al may foster skepticism, as it assumes the database employed by Sears et al adequately ensures that patients are

not lost to follow-up. Indeed, these authors emphasize that the MarketScan database allows for longitudinal follow-up and only included patients with at least 2 years of follow-up after initial treatment, whether that be either surgery or injection. This observation period is based on published typical time for recurrence of symptoms, and higher survival rates have been reported in the literature.¹² A second limitation of this study is that it makes no attempt to assess value. That is, this is not a study of cost-effectiveness, but instead cost-minimization, as defined from the payer perspective. It is for this reason we make no attempt to assess incremental cost-effectiveness ratios. Future studies may employ value-based cost analyses such as time-driven activity-based costing.¹⁴ However, this study's cost-minimization assessment via the payer perspective is not novel and has similarly been employed in an analysis of trigger finger treatment.¹⁵ Third, we do not employ the rate of complications for both surgery and injections, nor any additional costs that may be incurred from this morbidity. However, the rate of surgical complications is low,^{13,20} with a recent meta-analysis reporting a less than 3% incidence for open carpal tunnel release.²⁸ Even more rare are reported complications after injections, which are almost exclusively limited to case reports,^{19,22} and so the cost-related complications would likely further relatively increase the cost of surgery as compared with steroid injections. Fourth, this study does not attempt to account for nor assess long-term patient outcomes other than avoidance of surgery. Indeed, AAOS guidelines report strong evidence that surgical treatment has a greater benefit compared with nonoperative measures of splinting, anti-inflammatory medications, and steroid injections.¹ However, this recommendation lumps all conservative measures together, and the single study cited by the guidelines that compares steroid injection to surgical release at 12 months found no difference in clinical improvement in the 2 groups, although surgery patients improved more on neurophysiologic assessments.² Fifth, we do not attempt to assess the impact of many other variables that could affect treatment success probabilities. These include, but are not limited to, patient comorbidity, posttreatment protocols, and patient expectations. Finally, we assume that surgical intervention has a 100% success rate, which is not true.¹⁰ However, it is a reasonable approximation, and an adjustment to this figure would only further increase the relative expected cost of immediate surgical intervention.

Despite these limitations, the results of this analysis suggest that initial steroid injection incurs minimal direct cost for payers. Assuming a "medium" or 32% injection success rate, an approach utilizing a single steroid injection followed by surgery if needed results in an expected total treatment cost of \$1885 to \$7982 (Medicare to institutional billing) compared with \$2149 to \$9927 for immediate surgical release. This would save, on a per patient basis, \$264 if utilizing the conservative Medicare reimbursement

costs and substantially more—\$2080—if employing institutional billing charges. Extrapolating nationally, where 500 000 carpal tunnel surgeries are performed per year at an average cost of \$4000, this estimates a savings of \$359 million annually, a substantial cost mitigation. Moreover, if 2 or 3 injections are initially attempted before surgical release, this study's analysis suggests even more costs could be reduced. These specific extrapolations reflect employment of the "medium" steroid injection success rate of 32%. With the break-even probabilities of steroid success of 19.7% and 12.4% for Medicare reimbursement and institutional billing charges, respectively, which are at and below the low end of the literature's reported success rates for a steroid injection, it is difficult to conclude anything other than an initial trial of steroid injection as being a payer cost-minimizing approach to the management of carpal tunnel syndrome.

Still, it is imperative to reemphasize that this analysis only accounts for payer procedural costs, as well as the costs of splinting, and makes no attempt to account for other costs associated with surgical or nonsurgical management of carpal tunnel syndrome. It is for this reason that these findings are contradictory to other studies that favor immediate surgical release when assessing the cost-effective management of carpal tunnel syndrome. Indeed, studies that favor immediate surgical release attribute a majority of the nonoperative costs to hand therapy. In the study by Pomerance et al, assessing the cost-effectiveness of nonsurgical versus surgical treatment, over 50% of the cost of nonoperative management was due to therapist fees.²³ We believe this falsely inflates the expected cost of steroid treatment, as the senior author of our analysis does not routinely prescribe therapy after initial steroid injection. Moreover, no literature nor practice guidelines advocate for formal or home therapy as an adjunct to nonoperative management of carpal tunnel syndrome, and there is moderate evidence suggesting that formal therapy provides no added benefit after surgical release.^{1,8}

Although we find that initial and possibly repeat steroid injections is a cost-minimizing strategy for the treatment of carpal tunnel syndrome, we recognize that the optimal strategy is based on an informed choice of both physician and patient preference. For example, a patient's occupation may also play a role in his or her preferred management. Moreover, there are societal, psychosocial, and opportunity costs associated with a potentially prolonged course of nonoperative care. For these reasons, some patients may seek a definitive cure and be willing to accept the higher direct cost. However, others may strongly prefer all attempts at avoiding surgery. Those that lie between may be willing to attempt a single injection before deciding in favor of surgery. For these reasons, this study makes no attempt to say what is the best initial management option for carpal tunnel syndrome. It does, however, highlight that a trial of 1 to 3 steroid injections incurs the least

direct costs, and this benefit should be considered when deciding upon treatment.

Authors' Note

Investigation performed at the NYU Langone Orthopedic Hospital for Joint Diseases, New York, NY, USA.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Informed consent was obtained when necessary.

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.

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