

# Clinical quality measures for intraoperative and perioperative management in carpal tunnel surgery

Teryl K. Nuckols · Melinda Maggard Gibbons ·  
Neil G. Harness · Walter T. Chang · Kevin C. Chung ·  
Steven M. Asch · The Carpal Tunnel Quality Group

Published online: 5 March 2011

© The Author(s) 2011. This article is published with open access at Springerlink.com

## Abstract

**Background** Previous research documents suboptimal preoperative or postoperative care for patients undergoing surgery. However, few existing quality measures directly address the fundamental element of surgical care: intraoperative care processes. This study sought to develop

quality measures for intraoperative, preoperative, and postoperative care for carpal tunnel surgery, a common operation in the USA.

**Methods** We applied a variation of the well-established RAND/UCLA Appropriateness Method. Adherence to measures developed using this method has been associated with improved patient outcomes in several studies. Hand surgeons and quality measurement experts developed draft measures using guidelines and literature. Subsequently, in a two-round modified-Delphi process, a multidisciplinary panel of 11 national experts in carpal tunnel syndrome (including six surgeons) reviewed structured summaries of the evidence and rated the measures for validity (association with improved patient outcomes) and feasibility (ability to be assessed using medical records).

---

Members of the Carpal Tunnel Quality Group include Denis Chagnon, MD (Family Practice, Albany Memorial Hospital, Albany, NY, USA); Jeff Harris, MD (Occupational Medicine, Kaiser Permanente, San Rafael, California, CA, USA); Charles Jablecki, MD (Neurology, La Jolla, CA, USA); David Kilmer, MD (Physical Medicine and Rehabilitation, University of California, Davis, CA, USA; recently deceased); Peter Mandell, MD (Orthopedics, Burlingame, CA, USA); Daniel Mass, MD (Hand Surgery, University of Chicago, Chicago, IL, USA); Victoria Masear, MD (Hand Surgery, Birmingham, AL, USA); Mark Melhorne, MD (Hand Surgery, Wichita, KS, USA); Cuong Pho, DPT (Physical Therapy, Kaiser Permanente, Harbor City, CA, USA); and Rick Strain, MD (Orthopedics, Hollywood, FL, USA).

---

T. K. Nuckols (✉) · S. M. Asch  
RAND Corporation,  
1776 Main Street, P.O. Box 2138, Santa Monica,  
CA 90407–2138, USA  
e-mail: tnuckols@mednet.ucla.edu

N. G. Harness  
Kaiser Permanente Medical Group, Fontana Medical Center,  
Fontana, CA, USA

T. K. Nuckols · S. M. Asch  
Division of General Internal Medicine and Health Services  
Research, Department of Medicine,  
David Geffen School of Medicine, University of California,  
911 Broxton Plaza,  
Los Angeles, CA, USA

W. T. Chang  
Kaiser Permanente Medical Group,  
Yorba Linda, CA, USA

M. Maggard Gibbons  
Department of Surgery, David Geffen School of Medicine,  
University of California,  
Los Angeles, CA, USA

K. C. Chung  
Section of Plastic Surgery,  
The University of Michigan School of Medicine,  
Ann Arbor, MI, USA

M. Maggard Gibbons  
Olive View—UCLA Medical Center,  
Sylmar, CA, USA

S. M. Asch  
VA Greater Los Angeles Healthcare System,  
Los Angeles, CA, USA

**Results** Of 25 draft measures, panelists judged 22 (88%) to be valid and feasible. Nine intraoperative measures addressed the location and extent of surgical dissection, release after wrist trauma, endoscopic release, and four procedures sometimes performed during carpal tunnel surgery. Eleven measures covered preoperative and postoperative evaluation and management.

**Conclusions** We have developed several measures that experts, including surgeons, believe to reflect the quality of care processes occurring during carpal tunnel surgery and be assessable using medical records. Although quality measures like these cannot assess a surgeon's skill in handling the instruments, they can assess many important aspects of intraoperative care. Intraoperative measures should be developed for other procedures.

**Keywords** Carpal tunnel syndrome · Health care quality assurance · Standards · Surgery

Payers, policymakers, and surgeons are paying increasing attention to the quality of the surgical care provided in the USA. Better surgical care increases the likelihood that patients will experience favorable outcomes and be free of complications. From a societal standpoint, this may yield economic benefits by reducing disability and avoiding the medical care costs associated with complications. Consequently, efforts to measure and improve the quality of surgical care are becoming more widespread. The Surgical Care Improvement Project now sets national standards for process measures such as prophylactic antibiotics, prophylaxis against deep venous thrombosis, use of preoperative beta-blockers, and prevention of ventilator-associated pneumonia [12]. The high cost attributed to complications has convinced a number of insurance companies to subsidize surgeons' efforts to monitor and improve quality [5]. Similarly, Medicare has experimented with pay-for-performance incentives for physicians [12]. In the future, these national efforts to evaluate surgical quality of care are likely to expand.

To measure the quality of surgical care, specific measures are needed. Process-oriented measures identify care processes that patients should or should not receive under specified circumstances. The purpose of such measures is to make existing standards of care explicit and measurable. Generally, quality measures delineate basic standards of care, in contrast to guidelines, which describe both minimum standards and best practices [26].

Most process measures pertaining to surgical procedures address the appropriateness of surgery (i.e., whether the surgery should be performed or not), preoperative care, or postoperative care. Very few existing measures address the fundamental element of surgical care: care during an

operation. Yet good intraoperative care is critical to achieving favorable surgical outcomes. Some important aspects of intraoperative care are challenging to measure, such as the surgeon's dexterity in using the instruments or handling tissues. Nevertheless, other important aspects of intraoperative care can be assessed by reviewing operative reports and related records.

Our objective in this study was to develop a set of quality measures that can be used to assess, via medical record review, key aspects of intraoperative care as well as preoperative and postoperative care provided to patients undergoing carpal tunnel surgery. We chose to focus on carpal tunnel release surgery for two reasons. First, carpal tunnel syndrome causes substantial disability among working-age adults, which means that improving patient outcomes is likely to benefit both the affected individuals, through reduced symptoms, and their employers, through reduced absenteeism, improved productivity at work, and reduced healthcare expenditures [6]. Second, studies suggest that the outcomes of carpal tunnel surgery are not always optimal, with unsatisfactory results occurring in up to 10–15% of patients [1, 8, 13, 14]. Some variability in outcomes appears attributable to patient characteristics [1, 11]. However, some poor outcomes may be due to patients receiving less than optimal surgical care.

Quality measures should be based on high-quality studies whenever possible. However, randomized controlled trials do not exist for most healthcare processes, particularly many aspects of surgical care including intraoperative processes [2, 25]. We, therefore, developed these measures using a variation of the RAND/UCLA Appropriateness Method. A particular strength of this method is its ability to consider available evidence and overcome important gaps by rigorously synthesizing the experience of expert clinicians [7]. Syntheses of clinical expertise are a valid and important form of evidence, as demonstrated by the fact that better adherence to measures developed using this method have been associated with improved patient outcomes in multiple studies. For example, judgments about the appropriateness of carotid endarterectomy were consistent with the findings of a subsequent randomized trial [9, 10, 22]. For arthroplasty of the knee and hip, judgments about the appropriateness of surgery were associated with improved quality of life [20].

## Materials and Methods

Quality measure development follows a three-step process: (1) creating draft measures by integrating guidelines and literature, (2) refining and selecting final measures, and (3)

testing the measures against a data source. Here, we report on the first two steps and the results of early pilot testing. This was one aspect of an effort to develop quality measures for carpal tunnel syndrome; other measures have been reported separately [16, 17, 21].

### Developing Draft Measures

Developing draft measures was an iterative process involving collaboration among two hand surgeons, one general surgeon with experience developing measures of surgical quality, and two internists with expertise in quality measurement. First, we conducted a general literature search on carpal tunnel syndrome, searched MEDLINE, National Guidelines Clearinghouse, specialty society websites, and other sources of publicly available guidelines, and accessed personal reference collections. Team hand surgeons reviewed the guidelines and literature, chose key intraoperative and perioperative care processes that are likely to affect patient outcomes or that are widely recommended, then wrote draft measures.

Directed MEDLINE searches were conducted to identify evidence pertinent to the draft measures (search terms: surgery for carpal tunnel syndrome OR median neuropathy, additional MeSH terms used: surgical procedures, operative). For 845 citations identified, hand surgeons sequentially reviewed titles, abstracts, and articles to assess relevance to each draft measure. Draft measures were then refined, added, and deleted.

Next, the hand surgeons summarized, for each draft measure, the evidence supporting the relationship between the care process and patient outcomes, emphasizing the highest quality evidence identified. Given most evidence was not high quality, they used a simplified classification scheme: level 1, randomized controlled trial; 2, observational study; and 3, case series and expert opinion. Where level 1 evidence was not available, the summary described a chain of evidence or clinical rationale, including recommendations from recent guidelines.

### Refining and Selecting Measures

Methods for refining and selecting quality measures were derived from the RAND/UCLA Appropriateness Method, a multidisciplinary, two-round, modified-Delphi process that enables researchers to obtain a quantitative assessment that reflects the judgment of a group of experts [7]. This well-established method (described below) has been used to develop quality measures for surgical care and determine the appropriateness of many surgical procedures. The method has reproducibility consistent with that of well-accepted diagnostic tests like screening mammography—i.e., separate panels examining the same topic have produced similar recommen-

dations (kappas 0.51–0.83) [15, 23]. Further, the measures developed using this method have been shown to have content, construct, and predictive validity, as evidenced by the association between adherence to the measures and improved patient outcomes in multiple studies. Additional details about this method have been published previously [7, 22].

For this study, we selected a panel with 11 members: four hand surgeons, two orthopedists, an occupational medicine physician, a neurologist, a physiatrist, a family physician, and a physical therapist. Including a variety of clinical backgrounds is essential to the RAND/UCLA panel process because it increases the range of issues that the panel considers and discusses. National specialty societies recommended leaders in each specialty, and then we selected panelists representing a variety of geographic locations, expertise, and practice settings. Several surgeons were involved in the guideline development effort by the American Academy of Orthopedic Surgery (AAOS) [3, 4].

The first round of ratings involved having panelists rate the measures at home. Panelists received the evidence summaries, draft measures, ballots, and instructions. During the second round, panelists met in person and research team members moderated discussions of each draft measure, the evidence, and first-round ratings. This panel method allows different attitudes to be expressed and contend with one another in order to allow true agreement or disagreement to emerge. This is in contrast to a consensus-panel method, which typically forces the group to reach agreement. Panelists suggested modifications to definitions of key terms and measures; these were adopted when a majority voted to do so. After all opinions had been voiced for a measure, all panelists marked private, equally weighted ballots.

For both rounds, panelists rated validity, feasibility, and importance on 9-point scales (9=highest). Validity meant: (1) adequate scientific evidence or professional consensus exists to support a link between the performance of care specified by the measure and improved clinical outcomes; and (2) based on the panelists' professional experience, health professionals with significantly higher rates of adherence to a measure would be considered higher-quality providers. Panelists were also instructed that, for a measure to be valid, both the care itself and the documentation of that care in the medical record must be important reflections of quality. Following standard procedures for this panel method, we interpreted validity ratings as follows: valid=median of 7–9 without disagreement; not valid=median of 1–3 without disagreement; uncertain validity=median of 4–6, or any median with disagreement. Disagreement was defined as three or more panelists rating in the 1–3 range and three or more in the 7–9 range [7].

We also included feasibility and importance to enable future users to prioritize the measures. Feasibility meant the potential ability to evaluate adherence to the measure using

medical records as the only source of information on the care provided. Measures were considered infeasible if the median rating was below 4. Importance meant the magnitude of the potential effect on patient outcomes; there was no minimum threshold for importance.

### Pilot Testing

After identifying measures meeting the validity and feasibility criteria, RAND staff developed a detailed tool for scoring them and pilot tested the measures and tool in a large workers' compensation provider organization (Kaiser Permanente Northern California Regional Occupational Health) and in a large workers' compensation insurance company (the California State Compensation Insurance Fund) [18]. Six nurses and one physical therapist, who routinely perform claims reviews within each organization, underwent a 2-day training in the use of the tool and scored several practice cases. Finally, they reviewed records for 28 patients who had been diagnosed with carpal tunnel syndrome (CTS) or conditions often confused with CTS. During the training and pilot testing, these abstractors

provided feedback on the tool. The pilot test activities were approved by each of the institutional human subjects' protection committees; informed consent was not required.

## Results

### Panel Evaluation of Measures

We developed 24 draft measures and the panel made changes to all but two of them, including splitting one measure into two. Two intraoperative measures did not meet validity criteria. Panelists deleted one postoperative measure because it addressed a rare situation. The 22 remaining measures (88%) met the validity and feasibility criteria. For the intraoperative and perioperative measures, respectively, Tables 1 and 2 list the measures themselves. Tables 3 and 4 list median ratings for validity, feasibility, importance, and the highest level of supporting evidence.

The Appendix provides the rationale for each passing measure, including a summary of the relevant literature. For few, if any, of these measures was there a large randomized

**Table 1** Intraoperative care measures meeting validity and feasibility criteria

#	Measure
1	Indications for primary open rather than endoscopic release If a carpal tunnel release procedure is performed and the patient has a suspected mass lesion or one documented by MRI/CT or ultrasound within the carpal tunnel (e.g., ganglion cyst), severe rheumatoid arthritis, or severe tenosynovitis of the wrist in the medical record, then the release should be performed open rather than endoscopically
2	Prompt release in wrist injury If a patient has signs and/or symptoms of carpal tunnel syndrome following a distal radius fracture or other severe wrist injury and those symptoms worsen with closed reduction of the fracture or immobilization of the wrist injury, then carpal tunnel release surgery should be offered within 48 h
3	Documentation of proximal transverse incision location in endoscopic release If a patient undergoes endoscopic carpal tunnel release surgery, then there must be documentation in the operative report that the proximal transverse incision was ulnar to the palmaris longus or did not extend radial to the radial aspect of ring finger if the palmaris longus is absent
4	Documentation that deep surface of transverse carpal ligament was identified in endoscopic release If a patient undergoes endoscopic carpal tunnel release surgery, then there should be documentation in the operative report that the deep surface of the transverse carpal ligament was identified prior to transection
5	Documentation of transverse carpal ligament release If a patient undergoes carpal tunnel release surgery, then there must be documentation in the operative report that the transverse carpal ligament was released
6	Limit superficial epineurotomy to specific indications If a patient undergoes primary open carpal tunnel release surgery, then superficial epineurotomy should not be performed <i>unless</i> specific injury or scarring of the median nerve was present
7	Limit internal neurolysis to specific indications If a patient undergoes open carpal tunnel release surgery, then internal neurolysis should not be performed <i>unless</i> specific injury or scarring of the median nerve was present
8	Limit flexor tenosynovectomy to specific indications If a patient undergoes carpal tunnel release surgery and does not have concomitant severe proliferative tenosynovitis (e.g., gout, inflammatory arthritis, or infection), then a flexor tenosynovectomy should not be performed
9	Avoidance of routine transverse carpal ligament repair If a patient undergoes open carpal tunnel release surgery, then the transverse carpal ligament should not be repaired

**Table 2** Preoperative and postoperative care measures meeting validity and feasibility criteria

#	Measure
10	Recent preoperative visit with surgical team If a patient undergoes carpal tunnel release surgery, then there must be documentation of a visit between the operating surgeon (or member of the operating team) and patient within 1 month prior to the date of surgery
11	Required elements of general preoperative history If a patient undergoes carpal tunnel release surgery, then there must exist a detailed general medical history (or an update of a previously taken history specifying any changes or lack thereof) updated within 1 month prior to surgery including (a) medical co-morbidities (b) past surgical history (c) medications (d) “allergies” (medication intolerances) (e) general review of systems including at least two organ systems
12	Required elements of CTS-specific preoperative evaluation If a patient undergoes carpal tunnel release surgery, then there must be documentation by the operating surgeon (or member of the surgical team) specifically noting all three of the following (1) Presence or absence of paresthesias and/or pain in median-nerve distribution, (2) Physical examination findings including presence or absence weakness of median-nerve- innervated muscles and/or thenar atrophy, (3) Discussion of whether electrodiagnostic testing was performed and any results
13	Adequate documentation of any prior treatments for carpal tunnel syndrome If a patient undergoes carpal tunnel release surgery, then there must be documentation by operating surgeon (or member of the operating team) specifically noting the presence or absence of history of previous treatments for carpal tunnel syndrome
14	Preoperative electrodiagnostic testing for work-associated carpal tunnel syndrome If patient undergoes carpal tunnel release surgery and has carpal tunnel syndrome thought to be associated with their occupation, then the patient should undergo preoperative electrodiagnostic testing
15	Preoperative evaluation of any suspected cervical radiculopathy If a patient has carpal tunnel syndrome and any suspected cervical radiculopathy, then carpal tunnel release surgery should not be performed before the patient has been evaluated further with one or more of the following (1) EMG/NCS looking for radiculopathy, (2) cervical spine radiographs or MRI, or (3) referral to neurology, neurosurgery, or physical medicine
16	Consent for open procedure in planned endoscopic release If a patient undergoes an attempt at endoscopic carpal tunnel release surgery, then the patient should have been consented for possible open procedure
17	Requirement for at least one postoperative visit If a patient undergoes carpal tunnel surgery, then they must be seen by a medical provider or physical/occupational/hand therapist for a postoperative clinic appointment within the first 2 weeks
18	Required elements of any postoperative evaluation by surgical team If a patient undergoes carpal tunnel surgery and has one or more postoperative appointments with the surgical team, then, at the first such visit, a surgical team member should evaluate the current carpal tunnel-related symptoms because the response to surgery and the presence or absence of complications should be assessed so that problems can be identified and treated
19	Monitoring of any postoperative stiffness If a patient undergoes a carpal tunnel release and has finger stiffness postoperatively at 2 weeks, then they must be reevaluated within 2 weeks by the operative team
20	Management of any postoperative stiffness If a patient undergoes a carpal tunnel release and has finger stiffness postoperatively at 6 weeks, then they must be referred for physical/occupational/hand therapy
21	Monitoring of any lack of improvement If a patient undergoes a carpal tunnel release and does not experience significant improvement in symptoms during the first 3 months following surgery, then the surgeon should personally reexamine the patient at least one additional visit
22	Required elements of evaluation of any lack of improvement If a patient undergoes carpal tunnel release surgery and does not experience significant improvement in symptoms after surgery, then the patient should be evaluated for reasons for lack of improvement (unless the patient refuses) via at least one of the following performed within 1 year postoperatively (1) ordering one or more diagnostic tests, or (2) referring the patient to another specialist for a second opinion

**Table 3** Panelists' ratings and evidence level for intraoperative care measures

Measure title	Validity		Feasibility		Importance Median (range)	Evidence Level <sup>c</sup>
	Median <sup>a</sup> (range)	N (%) of ratings ≥7	Median <sup>b</sup> (range)	N (%) of ratings ≥4		
1. Indications for primary open rather than endoscopic release	8 (7–9)	11 (100)	8 (7–9)	11 (100)	8 (7–9)	3
2. Prompt release in wrist injury	7 (7–8)	11 (100)	7 (5–9)	11 (100)	8 (7–9)	3
3. Documentation of proximal transverse incision location in endoscopic release	7 (5–9)	8 (73)	6 (2–9)	10 (91)	7 (3–9)	3
4. Documentation that deep surface of transverse carpal ligament was identified in endoscopic release	7 (5–9)	10 (91)	7 (1–9)	9 (82)	7 (1–9)	3
5. Documentation of transverse carpal ligament release	8 (7–9)	11 (100)	5 (1–9)	9 (82)	8 (1–9)	3
6. Limit superficial epineurotomy to specific indications	7 (6–9)	10 (91)	8 (6–9)	11 (100)	8 (5–9)	1
7. Limit internal neurolysis to specific indications	8 (7–9)	11 (100)	8 (7–9)	11 (100)	8 (7–9)	1
8. Limit flexor tenosynovectomy to specific indications	7 (7–9)	11 (100)	8 (7–9)	11 (100)	8 (7–9)	1
9. Avoidance of routine transverse carpal ligament repair	7 (6–9)	10 (91)	8 (6–9)	11 (100)	8 (5–9)	3
Measures that did not meet validity criteria						
Documentation of distal forearm fascia release	5 (3–7)	4 (36)	5 (1–9)	8 (73)	5 (1–8)	N/A
Release of any concomitant proximal compression in the forearm	2 (1–7)	2 (18)	2 (1–7)	4 (36)	2 (1–7)	N/A

<sup>a</sup> Ratings ≥7 indicated panelists thought the measure was valid

<sup>b</sup> Ratings ≥4 indicated panelists thought the measure was potentially feasible

<sup>c</sup> Level of evidence: 1 randomized controlled trial, 2 observational data, 3 case series or expert consensus

controlled trial or high-quality observational study directly examining the effect of the care described. Nevertheless, in each instance, there is convincing chain of evidence or clinical rationale that supports the practice.

### Pilot Testing

Of 28 patients in the pilot study, 14 had CTS and underwent carpal tunnel surgery for the first time during the study period; one additional patient had undergone surgery in the past.

After reviewing the operative reports for the intraoperative measures, the abstractors reported that several measures were challenging to score because the reports used unusual and highly variable terms to describe the operations. To investigate these concerns, a general internal medicine physician performed spot implicit reviews of operative reports, observed the substantial variability in terminology, and concluded that individuals with specific training or experience writing or reviewing these types of operative reports would be required to score the intraoperative measures. The seven abstractors reported no feasibility concerns for the pre- and postoperative care measures.

### Discussion

We have developed nine measures that can be used to assess the quality of the intraoperative care provided to

patients undergoing carpal tunnel surgery, as well as 11 measures pertaining to pre- and postoperative care. A multidisciplinary panel of national experts in carpal tunnel syndrome, including several hand surgeons and orthopedists, rated these measures as valid reflections of quality and feasible for use with medical record review.

The preoperative measures are generally intended to ensure that surgeons are able to make an accurate diagnosis and adequately assess the potential risks and benefits of carpal tunnel surgery. Because an incorrect diagnosis is a common reason that patients do not improve after carpal tunnel surgery, these preoperative measures are likely to reduce unnecessary and inappropriate operations [24]. In contrast, the intraoperative measures are designed to reduce the risks of serious surgical complications and persistent CTS symptoms. Damage to the median nerve (or its palmar cutaneous branch) is a particularly severe and disabling complication that several measures (#1, 3, 4, and 6–9) are designed to prevent. The remaining intraoperative measures (#2 and 5) are intended to reduce the chance that symptoms will not improve after surgery, also a fairly common occurrence [24]. Several of the postoperative measures assess whether providers identify and respond to these types of problems appropriately.

We know of very few other existing quality measures that focus on the quality of intraoperative care processes, regardless of the type of procedure. Assessing surgical appropriateness or outcomes is far more common. For example, a 2006 systematic review of quality measures for



**Table 4** Panelists' ratings and evidence level for preoperative and postoperative quality measures

Measure	Validity		Feasibility		Importance Median (range)	Evidence Level <sup>c</sup>
	Median <sup>a</sup> (range)	N (%) of ratings $\geq 7$	Median <sup>b</sup> (range)	N (%) of ratings $\geq 4$		
<b>Preoperative care</b>						
10. Recent preoperative visit with surgical team	7 (2–9)	8 (73)	8 (3–9)	10 (91)	7 (2–9)	3
11. Required elements of general preoperative history						
(a) Medical co-morbidities	8 (7–9)	11 (100)	8 (7–9)	11 (100)	8 (6–9)	3
(b) Past surgical history	7 (3–9)	6 (55)	8 (4–9)	11 (100)	6 (3–8)	3
(c) Medications	7 (4–9)	10 (91)	8 (6–9)	11 (100)	7 (5–9)	3
(d) “Allergies” (medication intolerances)	7 (4–9)	8 (73)	8 (6–9)	11 (100)	8 (4–9)	3
(e) General review of systems including at least two organ systems	7 (3–9)	8 (73)	8 (6–9)	11 (100)	7 (3–8)	3
12. Required elements of CTS-specific preoperative evaluation	9 (7–9)	11 (100)	9 (7–9)	11 (100)	9 (7–9)	2 and 3
13. Adequate documentation of any prior treatments for carpal tunnel syndrome	8 (6–8)	8 (73)	8 (6–9)	11 (100)	8 (6–9)	2 and 3
14. Preoperative electrodiagnostic testing for work-associated carpal tunnel syndrome	9 (4–9)	10 (91)	9 (6–9)	11 (100)	9 (7–9)	2 and 3
15. Preoperative evaluation of any suspected cervical radiculopathy	7 (5–9)	8 (73)	7 (5–9)	11 (100)	8 (5–9)	3
16. Consent for open procedure in planned endoscopic release	7 (6–9)	10 (91)	8 (7–9)	11 (100)	7 (5–9)	2
<b>Postoperative care</b>						
17. Requirement for at least one postoperative visit	8 (7–9)	11 (100)	8 (6–9)	11 (100)	8 (6–9)	2
18. Required elements of any postoperative evaluation by surgical team	8 (7–9)	11 (100)	8 (7–9)	11 (100)	8 (7–9)	3
19. Monitoring of any postoperative stiffness	7 (6–9)	9 (82)	8 (6–9)	11 (100)	8 (5–9)	3
20. Management of any postoperative stiffness	7 (5–9)	9 (82)	8 (5–9)	11 (100)	8 (5–9)	3
21. Monitoring of any lack of improvement	7 (7–9)	11 (100)	8 (7–9)	11 (100)	8 (6–9)	3
22. Required elements of evaluation of any lack of improvement	7 (6–9)	10 (91)	8 (6–9)	11 (100)	7 (5–9)	3
<b>Measure deleted by panelists due to low frequency of occurrence</b>						
Evaluation of any new weakness or numbness developing postoperatively	N/A <sup>d</sup>		N/A		N/A	N/A

<sup>a</sup> Ratings  $\geq 7$  indicated panelists thought the measure was valid

<sup>b</sup> Ratings  $\geq 4$  indicated panelists thought the measure was potentially feasible

<sup>c</sup> Level of evidence: 1 randomized controlled trial, 2 observational data, 3 case series or expert consensus

<sup>d</sup> N/A not applicable

colon cancer identified several that assess the appropriateness of surgery, the type of procedure chosen, recurrence rates, complication rates, and mortality rates. None of the measures addressed specific intraoperative care processes [19].

The reason for this dearth in process measures for intraoperative care is unclear but it could relate to concerns about feasibility. Certainly, there are many critical aspects of the art of surgery that cannot be assessed by reviewing medical records, such as a surgeon's dexterity or meticulousness in achieving hemostasis. Nevertheless, operations are comprised of individual steps that surgeons can choose to perform or forgo, the purpose of operative reports is to document the steps taken, and the steps taken or foregone influence patient outcomes. For example, the number

of lymph nodes harvested during the resection of colon cancer has been shown to influence the likelihood of recurrence [19]. The intraoperative measures, we developed comprise discrete individual steps in the performance of carpal tunnel surgery. Each of these steps is, in the opinions of our national experts, likely to influence specific patient outcomes, for reasons outlined above and explained in detail in the [Appendix](#). Further, the panelists believed that documenting each of these steps in the medical record was essential to providing adequate quality surgical care.

The ultimate test of quality measures' feasibility involves applying them to medical records, and here we must acknowledge that our work to date is incomplete. Pilot testing the intraoperative measures enabled us to determine that nurses and general internists can have difficulty scoring

them because some operative reports describe the procedures using unusual or variable terms. Our panelists, who included several surgeons, were generally very confident that the measures would be feasible, as evidenced by the fact that median feasibility scores were 7 or higher for seven of the nine intraoperative measures. Future work will need to confirm the feasibility of these measures by having surgeons who operate on the hand, or perhaps specially trained nurses, score them. If the intraoperative measures must be scored by surgeons rather than nurses, this will increase the cost of assessing quality of care. However, operative reports are concise documents that are relatively easy to obtain and review.

We are also planning future work to confirm the validity of the measures we have developed. For quality measures, the ultimate test of validity entails assessing whether better adherence is associated with better patient outcomes. However, most quality measures in wide use today have yet to be tested in this manner. We have developed a project that would compare adherence to these measures with patients' clinical outcomes as well as assess the relationship between quality, outcomes, and the costs of care and disability due to CTS.

Once the feasibility and validity of these measures has been confirmed, there are several ways that they could be used. Individual surgeons can use these measures to evaluate the quality of the care they provide. In some fields, board recertification is now contingent upon providers engaging in such activities. Practices with multiple surgeons can evaluate quality for the practice and, if warranted, develop an infrastructure that supports improvement. Such organizational efforts are particularly likely to be effective because they leverage the contributions of many individuals, and enable systems to be established that make adherence simpler. Payers might consider using these measures as a basis for referring patients to higher-quality providers, or as a basis for offering higher-quality providers greater remuneration. Because it is easier for payers to obtain and review operative reports than the entire medical record, the payers may find the intraoperative measures more feasible than the pre- and postoperative ones, which will require access to clinic notes. Finally, researchers can identify factors associated with better quality.

For the purposes of improving care, quality measures are most useful when they address basic standards of care that have not already been widely implemented. We suspect that baseline rates of adherence will be higher for some of these measures than for others. For example, because Medicare and other payers require histories and physical examinations to include specific elements, we suspect that the stipulations of measure #11 will usually be met. In contrast, we expect that the incision location and release of the transverse carpal ligament (measures #3 and 4) may not be

documented consistently. Future research will be needed to confirm or refute these hypotheses.

These measures also have other limitations. As noted, not all important aspects of care for patients undergoing carpal tunnel surgery are amenable to direct measurement. Further, unique clinical circumstances can warrant exceptions to a measure. Justifiable exceptions are not problematic so long as they are rare and randomly distributed among populations of patients. The literature examining these practices is rather limited, and most of the measures are based on expert consensus. In contrast to some fields, such as cardiology, both musculoskeletal disorders and surgical care suffer for a lack of large, high-quality randomized controlled trials. Trials are not possible for all important care processes, however. For example, it would be unethical to randomly assign an incision location that can damage to the palmar cutaneous branch of the median nerve. The panel method we used offers a rigorous and ethically acceptable approach to determining the right care in such clinical situations.

In conclusion, this project has developed a set of measures that can be used to evaluate the quality of the care provided to populations of patients undergoing carpal tunnel surgery. The several measures focusing on intraoperative care processes represent an important advance in the science of measuring quality of care. These measures will be useful in efforts to improve quality of care for patients with carpal tunnel syndrome, whether initiated by providers, medical groups, payers, or policymakers. Intraoperative measures should be developed for other common operations.

**Acknowledgments** The assistance of Christine Baker, MS, Executive Director of the California Commission on Health and Safety and Workers' Compensation, made this project possible. RAND staff members Rebecca Shaw, Belle Griffin, Liisa Hiatt, and Krasimir Karamfilov provided assistance with the research. We are grateful to the following individuals for their assistance: D. Lachlan Taylor, JD (Workers' Compensation Judge, California Commission on Health & Safety and Workers' Compensation), Doug Benner, MD (Medical Director, Regional Occupational Health, Kaiser Permanente Northern California), Gideon Letz, MD (Medical Director, California State Compensation Fund), Bernyce Peplowski, MD (past Medical Director, Zenith Insurance), Kathryn Mueller MD, MPH (Director for the Colorado Division of Workers' Compensation), and Jane Dereberry, MD (past Chairman, Concentra Occupational Health Research Institute, Austin, TX).

**Funding Source** This project was jointly supported by the California Commission on Health and Safety and Workers' Compensation, a state-sponsored joint labor-management body charged with overseeing the health and safety and workers' compensation systems in California and recommending administrative or legislative modifications to improve their operation, and by Zenith Insurance, a workers' compensation insurance company based in Woodland Hills, California. The RAND/UCLA team was fully responsible for the design and execution of this study, and the reporting of these results; the funders played no role in these activities.



**Open Access** This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited.

## Appendix

### Intraoperative Care Measures Meeting Validity and Feasibility Criteria

1. Indications for Primary Open Rather Than Endoscopic Release: Panelists identified two compelling indications for performing carpal tunnel surgery open: (1) a mass lesion in the canal, and (2) severe proliferative tenosynovitis. These conditions can impair endoscopic visualization of the undersurface of the transverse carpal ligament, which is critical to avoiding unintentional nerve injury. Mass lesions can include bone spurs, ganglion cysts, etc.,<sup>1</sup> and may be suspected clinically or on imaging. Patients with severe rheumatoid arthritis are at risk for having tenosynovitis.
2. Prompt Release in Wrist Injury: Swelling or hematoma formation within or near the median nerve can lead to carpal tunnel symptoms, as can displaced bone from a fracture.<sup>2</sup> If unrelieved, this can lead to permanent nerve injury. The panelists concluded that it is necessary to perform carpal tunnel surgery urgently when carpal tunnel symptoms develop following a severe wrist injury and persist despite treatment of the injury.
3. Documentation of Proximal Transverse Incision Location in Endoscopic Release: For endoscopic carpal tunnel surgery, a transverse incision crossing radial to the palmaris longus tendon is a common cause of injury to the palmar cutaneous branch of the median nerve.<sup>3</sup> Placing the incision ulnar to the palmaris longus tendon (or, if the palmaris longus is absent, radial to the radial aspect of the ring finger) reduces this risk. Panelists felt that documenting the incision's location is important. For example, such documentation is helpful when patients present postoperatively with new pain, tenderness, or numbness.
4. Documentation that Deep Surface of Transverse Carpal Ligament was Identified in Endoscopic Release: During endoscopic carpal tunnel surgery, attempting to transect the transverse carpal ligament without visualizing its deep surface increases the risk of damaging adjacent structures, including the median nerve.<sup>4–6</sup> Extra-bursal endoscopic carpal tunnel surgery with direct visualization of the transverse carpal ligament led to fewer complications in a multicenter study comparing the extra-bursal two-incision Chow technique with intra-bursal release.<sup>4</sup> Panelists believed that documentation that the transverse carpal ligament was visualized is important. For example, such documentation is helpful when present postoperatively with numbness or weakness in the median-nerve distribution.
5. Documentation of Transverse Carpal Ligament Release: Incomplete release of the transverse carpal ligament is one of the more common complications of carpal tunnel surgery<sup>7–10</sup> and the most common reason that symptoms fail to improve.<sup>11</sup> Panelists believed that documentation that the transverse carpal ligament was, in fact, released, therefore, was essential in case patients' symptoms fail to improve postoperatively.
6. Limit Superficial Epineurotomy to Specific Indications: Microscopic epineural scarring or fibrosis was once hypothesized to contribute to carpal tunnel syndrome, leading some surgeons to routinely perform epineurotomy with open carpal tunnel surgery. However, level 1 evidence from multiple studies indicates that this practice is of no benefit,<sup>12–14</sup> and the additional manipulation of the nerve may increase the risk of injury. Consequently, panelists concluded that epineurotomy is inappropriate unless scarring of the median nerve (or another injury) is present.
7. Limit Internal Neurolysis to Specific Indications: Routine internal neurolysis was once advocated for similar reasons as epineurotomy.<sup>15</sup> Subsequently, level 1 evidence from multiple studies has demonstrated no benefit.<sup>16–19</sup> Because internal neurolysis requires a more extensive dissection using a microscope and micro-instruments, it may increase the risk of nerve injury and peri-neural scarring.<sup>10</sup> The panelists believed that, in the absence of a specific indication, such as injury or scarring of the nerve, performing internal neurolysis is inappropriate.
8. Limit Flexor Tenosynovectomy to Specific Indications: Performing tenosynovectomy is unproven but generally accepted for conditions that cause tenosynovitis, such as gout, rheumatoid arthritis and diabetes mellitus. Tenosynovitis can cause recurrent carpal tunnel syndrome,<sup>20, 21</sup> and tenosynovectomy may prevent this.<sup>22</sup> However, in a prospective trial addressing the utility of *routine* tenosynovectomy in 87 patients undergoing carpal tunnel surgery, no benefit was observed.<sup>23</sup> Further, the additional dissection increases the risk of nerve injury or scarring. The panelists concluded that tenosynovectomy is inappropriate in the absence of documented tenosynovitis or the conditions associated with it.
9. Avoidance of Routine Transverse Carpal Ligament Repair: Reconstructing the transverse carpal ligament following transection has been hypothesized to prevent

postoperative “bowstringing” of the flexor tendons (bulging toward the volar surface of the wrist), improve grip strength,<sup>24, 25</sup> protect the median nerve, and preserve nerve gliding.<sup>26</sup> One small non-randomized prospective study with short-term follow-up demonstrated increased grip strength in the group with transverse carpal ligament repair compared with a control group.<sup>27</sup> However, transverse carpal ligament repair requires extensive dissection and release of Guyon’s canal with mobilization of the ulnar nerve and artery, which may increase the risk of complications, including recurrent carpal tunnel syndrome.<sup>8</sup> Flexor tendon bowstringing is an uncommon complication<sup>28</sup> and, if it does occur, the transverse carpal ligament can be reconstructed with a free tendon graft.<sup>7</sup> Therefore, the panelists concluded that routine transverse carpal ligament repair is inappropriate.

#### *Rationale for Preoperative Care Measures*

10. Recent Preoperative Visit With Surgical Team: Panelists believed that it is necessary for the operative team to evaluate a patient shortly before carpal tunnel surgery because co-morbid conditions, symptoms and signs can change over time and influence the appropriateness of surgery as well as the appropriate operative approach.
11. Required Elements of General Preoperative History: The panel believed that a recent, detailed preoperative history can influence perioperative management as well as outcomes. Co-existent medical conditions, particularly rheumatoid arthritis and diabetes are common among carpal tunnel syndrome patients.<sup>29, 30</sup> Rheumatoid arthritis can influence the operative technique (see below), and hyperglycemia may influence operative outcomes.<sup>31</sup> Current medication lists, medication intolerances (“allergies”), past surgical history, and a review of systems can influence the selection of anesthesia and pain medications as well as the operative approach. A general history can be obtained by providers other than the hand surgeon.
12. Required Elements of CTS-Specific Preoperative Evaluation: Documenting carpal tunnel symptoms, signs, and the results of electrodiagnostic testing before carpal tunnel surgery is necessary for the surgical team to do because there is no single method for confirming carpal tunnel syndrome,<sup>32, 33</sup> and an incorrect diagnosis is a common reason for lack of improvement after carpal tunnel surgery.<sup>11</sup> On the basis of a meta-regression analysis, the AAOS guideline concluded that clinical and electrodiagnostic tests together, but neither alone, were significantly associated with positive surgical outcomes.<sup>34</sup> An earlier systematic review comparing symptoms and signs against electrodiagnostic test results concluded that classic or high probability symptoms on a Katz hand diagram, weakness on thumb abduction strength testing, and hypalgesia of second digit adequately distinguish carpal tunnel syndrome from other conditions.<sup>32</sup> Other studies have found that thenar atrophy is associated with a lower likelihood of symptom resolution following carpal tunnel surgery.<sup>35, 36</sup> The current panel felt that a basic standard of care involves documenting the presence or absence symptoms in the median-nerve distribution, thenar muscle weakness (whether abduction or opposition is tested) or thenar atrophy, and electrodiagnostic test results.
13. Adequate Documentation of Any Prior Treatments for Carpal Tunnel Syndrome: Documenting whether a patient has undergone any previous carpal tunnel syndrome treatments is necessary for the surgical team to do because this has prognostic and therapeutic implications. Relief of symptoms following steroid injection into the carpal tunnel is predictive of better results following carpal tunnel surgery.<sup>35, 37, 38</sup> Further, the current panel found responses to splinting, activity modification, and steroid injection relevant to determining whether carpal tunnel surgery is indicated or not.<sup>39</sup>
14. Preoperative Electrodiagnostic Testing for Work-Associated Carpal Tunnel Syndrome: The panelists concluded that, while preoperative electrodiagnostic testing is generally recommended, it is essential when carpal tunnel syndrome appears work-associated. Many observational studies have found patients with workers’ compensation claims have worse functional and disability outcomes following carpal tunnel surgery than patients without such claims.<sup>40–46</sup> Therefore, a higher degree of preoperative diagnostic certainty is required for workers’ compensation patients.
15. Preoperative Evaluation of Any Suspected Cervical Radiculopathy: When providers suspect that a patient might have cervical radiculopathy in addition to or instead of carpal tunnel syndrome, the panelists felt that evaluating the cervical spine is necessary before carpal tunnel surgery because undiagnosed cervical radiculopathy is a common reason that carpal tunnel-like symptoms persist following carpal tunnel surgery.<sup>47–50</sup> Electrodiagnostic testing,<sup>50</sup> obtaining cervical spine radiographs or magnetic resonance imaging,<sup>51</sup> or referring a patient to another provider with expertise in nerve impingement syndromes can be helpful.

16. Consent for Open Procedure in Planned Endoscopic Release: When an endoscopic carpal tunnel surgery is planned, the panelists believed that obtaining informed consent for a possible conversion to an open approach is necessary because conversions occur in about 2.5% of cases.<sup>52, 53</sup>

#### *Rationale for Postoperative Care Measures*

17. Requirement for at Least One Postoperative Visit: At least one visit with the surgical team, a medical provider, or therapist who treats hand disorders is necessary within 2 weeks after carpal tunnel surgery because many patients experience treatable short-term adverse effects. In one study, carpal tunnel surgery patients experienced scar pain or hypertrophy (61%), stiffness (28%), skin irritation (28%), hematoma (11%), and infection (6%).<sup>54</sup> The panelists did not believe that the postoperative visit has to be with a hand surgeon, however, because outcomes are similar when patients follow-up with general practitioners (except they may over-diagnose infections).<sup>55</sup>
18. Required Elements of Any Postoperative Evaluation by Surgical Team: The panelists believed that documenting any change in carpal tunnel syndrome symptoms after carpal tunnel surgery is important for the operating team to do because these symptoms are the principal reason for performing carpal tunnel surgery, can worsen after surgery,<sup>54</sup> and warranted evaluation if they persist.
19. Monitoring of Postoperative Stiffness: When patients present with postoperative stiffness at early postoperative visits, the panelists concluded that reevaluation by the surgical team is necessary so that the team can determine whether hand therapy is indicated (below).
20. Management of Postoperative Stiffness: One prospective randomized controlled study of 100 patients undergoing carpal tunnel surgery assessed routine postoperative hand therapy and found return to work was faster (32 vs. 43 days,  $p < 0.006$ ),<sup>56</sup> suggesting that hand therapy may influence functional status. Panelists believed that patients who experience postoperative stiffness at 6 weeks are at increased risk for delayed recovery of functional status and that referral for hand therapy is necessary.
21. Monitoring for Lack of Improvement: The panelists believed that, when patients do not exhibit improvement by 3 months postoperatively, it is necessary for the surgeon to monitor them further because, if this persists, evaluation is warranted (below).
22. Required Elements of Evaluation if Lack of Symptomatic Improvement: Evaluating patients who do not

exhibit improvement following carpal tunnel surgery is necessary within 1 year, the panelists concluded. Given the broad range of issues that may prevent symptomatic improvement,<sup>11</sup> the evaluation may include a variety of diagnostic tests or an evaluation by other providers with relevant expertise. The evaluation should occur within a year given that symptoms generally resolve or plateau by 6 months.<sup>57–60</sup>

#### References

1. al-Qattan MM, Bowen V, Manktelow RT. Factors associated with poor outcome following primary carpal tunnel release in non-diabetic patients. *J Hand Surg Br.* 1994;19(5):622–5.
2. American Academy of Orthopaedic Surgeons (AAOS). Clinical Guideline on Diagnosis of Carpal Tunnel Syndrome: Guideline. Rosemont, IL 2007; Available at: <http://www.aaos.org/Research/guidelines/guide.asp> and [http://www.aaos.org/Research/guidelines/CTS\\_guideline.pdf](http://www.aaos.org/Research/guidelines/CTS_guideline.pdf).
3. American Academy of Orthopaedic Surgeons (AAOS). CTS Workgroup Approval Funding. 2007. Available at: <http://www.aaos.org/Research/guidelines/CTSWorkgroupApprovalFunding.pdf>.
4. American Academy of Orthopaedic Surgeons (AAOS). Clinical Practice Guideline on the Treatment of Carpal Tunnel Syndrome. 2008. Available at: <http://www.aaos.org/Research/guidelines/CTSTreatmentGuideline.pdf>.
5. Englesbe MJ, Dimick JB, Sonnenday CJ, Share DA, Campbell Jr DA. The Michigan surgical quality collaborative: will a statewide quality improvement initiative pay for itself? *Ann Surg.* 2007;246(6):1100–3.
6. Feuerstein M, Miller VL, Burrell LM, Berger R. Occupational upper extremity disorders in the federal workforce. Prevalence, health care expenditures, and patterns of work disability. *J Occup Environ Med.* 1998;40(6):546–55.
7. Fitch K, Bernstein SJ, Aguilar MD, Burnand B, LaCalle JR, Lazaro P, et al. The RAND/UCLA Appropriateness Method User's Manual. Santa Monica, CA: RAND Corporation 2001. Report No.: MR-1269-DG-XII/RE; Available at: [http://www.rand.org/health/surveys\\_tools/appropriateness.html](http://www.rand.org/health/surveys_tools/appropriateness.html), last accessed January 31, 2011.
8. Gerritsen AAM, de Vet HCW, Scholten RJP, Bertelsmann FW, de Krom MCTFM, Bouter LM. Splinting versus surgery in the treatment of carpal tunnel syndrome. A randomized controlled trial. *JAMA.* 2002;288(10):1245–51.
9. Hepner KA, Rowe M, Rost K, Hickey SC, Sherbourne CD, Ford DE, et al. The effect of adherence to practice guidelines on depression outcomes. *Ann Intern Med.* 2007;147(5):320–9.
10. Higashi T, Shekelle PG, Adams JL, Kamberg CJ, Roth CP, Solomon DH, et al. Quality of care is associated with survival in vulnerable older patients. *Ann Intern Med.* 2005;143(4):274–81.
11. Higgs PE, Edwards D, Martin DS, Weeks PM. Carpal tunnel surgery outcomes in workers: effect of workers' compensation status. *J Hand Surg Am.* 1995;20(3):354–60.
12. Jones RS, Brown C, Opelka F. Surgeon compensation: "Pay for performance", the American College of Surgeons national surgical quality improvement program, the surgical care improvement program, and other considerations. *Surgery.* 2005;138(5):829–36.
13. Katz JN, Keller RB, Simmons BP, Rogers WD, Bessette L, Fossel AH, et al. Maine Carpal Tunnel study: outcomes of operative and nonoperative therapy for carpal tunnel syndrome in a community-based cohort. *J Hand Surg Am.* 1998;23(4):697–710.

14. Katz JN, Losina E, Amick 3rd BC, Fossel AH, Bessette L, Keller RB. Predictors of outcomes of carpal tunnel release. *Arthritis Rheum.* 2001;44(5):1184–93.
15. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics.* 1977;33:159–74.
16. Maggard MA, Harness NG, Chang WT, Parikh JA, Asch SM, Nuckols TK. Indications for performing carpal tunnel surgery: clinical quality measures. *Plast Reconstr Surg.* 2010;126(1):169–79.
17. Nuckols T, Harber P, Sandin K, Benner D, Weng H, Shaw R, et al. Quality measures for the diagnosis and non-operative management of carpal tunnel syndrome in occupational settings. *J Occup Rehabil.* 2010. doi:10.1007/s10926-010-9260-6.
18. Nuckols T, Griffin A, Asch S, Benner D, Bruce E, Cassidy M, et al. (2011) Quality-of-care measures for carpal tunnel syndrome: data collection tools to use when applying the measures: RAND (in press).
19. Patwardhan MB, Samsa GP, McCrory DC, Fisher DA, Mantyh CR, Morse MA, et al. Cancer care quality measures: diagnosis and treatment of colorectal cancer (Evidence Report #138). Rockville, MD: Agency for Healthcare Research and Quality 2006. Available at: <http://www.ahrq.gov/downloads/pub/evidence/pdf/colocanqm/colocanqm.pdf>.
20. Quintana JM, Escobar A, Arostegui I, Bilbao A, Azkarate J, Goenaga JI, et al. Health-related quality of life and appropriateness of knee or hip joint replacement. *Arch Intern Med.* 2006;166(2):220–6.
21. Sandin KJ, Asch SM, Jablecki CK, Kilmer DD, Nuckols TK. Clinical quality measures for electrodiagnosis in suspected carpal tunnel syndrome. *Muscle Nerve.* 2010;41(4):444–52.
22. Shekelle PG. The appropriateness method. *Med Decis Making.* 2004;24(2):228–31.
23. Shekelle PG, Kahan JP, Bernstein SJ, Leape LL, Kamberg CJ, Park RE. The reproducibility of a method to identify the overuse and underuse of medical procedures. *N Engl J Med.* 1998;338(26):1888–95.
24. Steyers CM. Recurrent carpal tunnel syndrome. *Hand Clin.* 2002;18(2):339–45.
25. US Institute of Medicine. Committee for evaluating medical technologies in clinical use. *Assessing Medical Technologies.* Washington, DC: National Academy Press; 1985.
26. Walter LC, Davidowitz NP, Heineken PA, Covinsky KE. Pitfalls of converting practice guidelines into quality measures: lessons learned from a VA performance measure. *JAMA.* 2004;291(20):2466–70.
7. MacDonald RI, Lichtman DM, Hanlon JJ, Wilson JN. Complications of surgical release for carpal tunnel syndrome. *J Hand Surg [Am].* 1978;3(1):70–76.
8. Kessler FB. Complications of the management of carpal tunnel syndrome. *Hand Clin.* 1986;2(2):401–406.
9. Das SK, Brown HG. In search of complications in carpal tunnel decompression. *Hand.* 1976;8(3):243–249.
10. Urbaniak JR, Desai SS. Complications of nonoperative and operative treatment of carpal tunnel syndrome. *Hand Clin.* 1996;12(2):325–335.
11. Steyers CM. Recurrent carpal tunnel syndrome. *Hand Clin.* 2002;18(2):339–345.
12. Foulkes GD, Atkinson RE, Beuchel C, Doyle JR, Singer DI. Outcome following epineurotomy in carpal tunnel syndrome: a prospective, randomized clinical trial. *J Hand Surg [Am].* 1994;19(4):539–547.
13. Leinberry CF, Hammond 3rd NL, Siegfried JW. The role of epineurotomy in the operative treatment of carpal tunnel syndrome. *J Bone Joint Surg Am.* 1997;79(4):555–557.
14. Blair WF, Goetz DD, Ross MA, Steyers CM, Chang P. Carpal tunnel release with and without epineurotomy: a comparative prospective trial. *J Hand Surg [Am].* 1996;21(4):655–661.
15. Curtis RM, Eversmann Jr WW. Internal neurolysis as an adjunct to the treatment of the carpal-tunnel syndrome. *J Bone Joint Surg Am.* 1973;55(4):733–740.
16. Holmgren-Larsson H, Leszniewski W, Lindén U, Rabow L, Thorling J. Internal neurolysis or ligament division only in carpal tunnel syndrome - results of a randomized study. *Acta Neurochir (Wien).* 1985;74(3–4):118–121.
17. Holmgren H, Rabow L. Internal neurolysis or ligament division only in carpal tunnel syndrome. II. A 3 year follow-up with an evaluation of various neurophysiological parameters for diagnosis. *Acta Neurochir (Wien).* 1987;87(1–2):44–47.
18. Mackinnon SE, McCabe S, Murray JF, et al. Internal neurolysis fails to improve the results of primary carpal tunnel decompression. *J Hand Surg [Am].* 1991;16(2):211–218.
19. Lowry Jr WE, Follender AB. Interfascicular neurolysis in the severe carpal tunnel syndrome. A prospective, randomized, double-blind, controlled study. *Clin Orthop Relat Res.* 1988;227:251–254.
20. Botte MJ, Von Schroeder HP, Abrams RA, Gellman H. Recurrent carpal tunnel syndrome. *Hand Clin.* 1996;12(4):731–743.
21. Wheatley MJ, Kaul MP. Recurrent carpal tunnel syndrome following endoscopic carpal tunnel release: a preliminary report. *Ann Plast Surg.* 1997;39(5):469–471.
22. Ting J, Weiland AJ. Role of ancillary procedures in surgical management of carpal tunnel syndrome: epineurotomy, internal neurolysis, tenosynovectomy, and tendon transfers. *Hand Clin.* 2002;18(2):315–323.
23. Shum C, Parisien M, Strauch RJ, Rosenwasser MP. The role of flexor tenosynovectomy in the operative treatment of carpal tunnel syndrome. *J Bone Joint Surg Am.* 2002;84-A(2):221–225.
24. Netscher D, Valkov PL. The benefit of transverse carpal ligament reconstruction following open carpal tunnel release. *Atlas of the Hand Clinics.* 2002;7(2):243.
25. Jakab E, Ganos DE, Cook FW. Transverse carpal ligament reconstruction in surgery for carpal tunnel syndrome: a new technique. *J Hand Surg [Am].* 1991;16(2):202–206.
26. Hunter JM. Reconstruction of the transverse carpal ligament to restore median nerve gliding. The rationale of a new technique for revision of recurrent median nerve neuropathy. *Hand Clin.* 1996;12(2):365–378.
27. Netscher D, Steadman AK, Thomby J, Cohen V. Temporal changes in grip and pinch strength after open carpal tunnel release and the effect of ligament reconstruction. *J Hand Surg [Am].* 1998;23(1):48–54.

## References for Appendices

1. Harvey FJ, Bosanquet JS. Carpal tunnel syndrome caused by a simple ganglion. *Hand.* 1981;13(2):164–166.
2. Raskin K, Klugman J, Rettig ME. Median Nerve Injuries Associated with Distal Radius Fractures: Current Concepts in Management. *Atlas of the Hand Clinics.* 2002;7(2):259–272.
3. Braun RM, Rechin M, Fowler E. Complications related to carpal tunnel release. *Hand Clin.* 2002;18(2):347–357.
4. Nagle DJ, Fischer TJ, Harris GD, et al. A multicenter prospective review of 640 endoscopic carpal tunnel releases using the trans-bursal and extrabursal chow techniques. *Arthroscopy.* 1996;12(2):139–143.
5. Brown RA, Gelberman RH, Seiler JG, et al. Carpal tunnel release. A prospective, randomized assessment of open and endoscopic methods. *J Bone Joint Surg Am.* 1993;75(9):1265–1275.
6. Thoma A, Veltri K, Haines T, Duku E. A meta-analysis of randomized controlled trials comparing endoscopic and open carpal tunnel decompression. *Plast Reconstr Surg.* 2004;114(5):1137–1146.



28. Green DP, Hotchkiss R, Pederson WC. *Green's Operative Hand Surgery*. Oxford, England: Churchill Livingstone; 2005.
29. Michelsen H, Posner MA. Medical history of carpal tunnel syndrome. *Hand Clin*. 2002;18(2):257–268.
30. Stevens JC, Beard CM, O'Fallon WM, Kurland LT. Conditions associated with carpal tunnel syndrome. *Mayo Clin Proc*. 1992;67(6):541–548.
31. Trick WE, Scheckler WE, Tokars JI, et al. Risk factors for radial artery harvest site infection following coronary artery bypass graft surgery *Clin Infect Dis*. 2000;30(2):270–275.
32. D'Arcy CA, McGee S. Does this patient have carpal tunnel syndrome? *JAMA*. 2000;283(23):3110–3117.
33. Rempel D, Evanoff B, Amadio PC, et al. Consensus criteria for the classification of carpal tunnel syndrome in epidemiologic studies. *Am J Public Health*. 1998;88(10):1447–1451.
34. American Academy of Orthopaedic Surgeons (AAOS). Diagnosis of Carpal Tunnel Syndrome: Evidence Report. Available at: <http://www.aaos.org/Research/guidelines/guide.asp> and [http://www.aaos.org/Research/guidelines/CTS\\_body.pdf](http://www.aaos.org/Research/guidelines/CTS_body.pdf).
35. Kulick MI, Gordillo G, Javidi T, Kilgore Jr ES, Newmayer 3rd WL. Long-term analysis of patients having surgical treatment for carpal tunnel syndrome. *J Hand Surg [Am]*. 1986;11(1):59–66.
36. Mühlau G, Both R, Kunath H. Carpal tunnel syndrome—course and prognosis. *J Neurol*. 1984;231(2):83–86.
37. Green DP. Diagnostic and therapeutic value of carpal tunnel injection. *J Hand Surg [Am]*. 1984;9(6):850–854.
38. Edgell SE, McCabe SJ, Breidenbach WC, LaJoie AS, Abell TD. Predicting the outcome of carpal tunnel release. *J Hand Surg [Am]*. 2003;28(2):255–261.
39. Maggard M, Harness N, Chang W, Asch S, Nuckols T, The Carpal Tunnel Quality Group. Clinical Quality Measures for the Decision to Perform Carpal Tunnel Release Surgery. *Unpublished*. 2008.
40. Higgs PE, Edwards D, Martin DS, Weeks PM. Carpal tunnel surgery outcomes in workers: effect of workers' compensation status. *J Hand Surg [Am]*. 1995;20(3):354–360.
41. Katz JN, Amick 3rd BC, Keller R, et al. Determinants of work absence following surgery for carpal tunnel syndrome. *Am J Ind Med*. 2005;47(2):120–130.
42. Katz JN, Keller RB, Simmons BP, et al. Maine Carpal Tunnel Study: outcomes of operative and nonoperative therapy for carpal tunnel syndrome in a community-based cohort. *J Hand Surg [Am]*. 1998;23(4):697–710.
43. Katz JN, Keller RBF, A. H., Punnett L, Bessette L, Simmons BP, Mooney N. Predictors of return to work following carpal tunnel release. *Am J Ind Med*. 1997;31(1):85–91.
44. Katz JN, Lew RA, Bessette L, et al. Prevalence and predictors of long-term work disability due to carpal tunnel syndrome. *Am J Ind Med*. 1998;33(6):543–550.
45. Carmona L, Faucett J, Blanc PD, Yelin E. Predictors of rate of return to work after surgery for carpal tunnel syndrome. *Arthritis Care Res*. 1998;11(4):298–305.
46. Amick 3rd BC, Habeck RV, Ossmann J, Fossel AH, Keller R, Katz JN. Predictors of successful work role functioning after carpal tunnel release surgery. *J Occup Environ Med*. 2004;46(5):490–500.
47. Hybbinette CH, Mannerfelt L. The carpal tunnel syndrome. A retrospective study of 400 operated patients. *Acta Orthop Scand*. 1975;46(4):610–620.
48. Eason SY, Belsole RJ, Greene TL. Carpal tunnel release: analysis of suboptimal results. *J Hand Surg [Br]*. 1985;10(3):365–369.
49. Epstein NE, Epstein JA, Carras R. Coexisting cervical spondylotic myelopathy and bilateral carpal tunnel syndromes. *J Spinal Disord*. 1989;2(1):36–42.
50. Witt JC, Stevens JC. Neurologic disorders masquerading as carpal tunnel syndrome: 12 cases of failed carpal tunnel release. *Mayo Clin Proc*. 2000;75(4):409–413.
51. Plancher KD. *MasterCases in Hand and Wrist Surgery*. New York, NY: Thieme Medical Publishers; 2004.
52. Kozin SH. Single-Portal Endoscopic Carpal Tunnel Release. *Atlas of Hand Clinics*. 2002;7:229–241.
53. Agee JM, Peimer CA, Pyrek JD, Walsh WE. Endoscopic carpal tunnel release: a prospective study of complications and surgical experience. *J Hand Surg [Am]*. 1995;20(2):165–171.
54. Gerritsen AAM, de Vet HCW, Scholten RJPM, Bertelsmann FW, de Krom MCTFM, Bouter LM. Splinting versus surgery in the treatment of carpal tunnel syndrome. A randomized controlled trial. *JAMA*. 2002;288(10):1245–1251.
55. Atherton WG, Faraj AA, Riddick AC, Davis TR. Follow-up after carpal tunnel decompression - general practitioner surgery or hand clinic? A randomized prospective study. *J Hand Surg [Br]*. 1999;24(3):296–297.
56. Provinciali L, Giattini A, Splendiani G, Logullo F. Usefulness of hand rehabilitation after carpal tunnel surgery. *Muscle Nerve*. 2000;23(2):211–216.
57. Burke FD, Wilgis EF, Dubin NH, Bradley MJ, Sinha S. Relationship between the duration and severity of symptoms and the outcome of carpal tunnel surgery. *J Hand Surg [Am]*. 2006;31(9):1478–1482.
58. Guyette TM, Wilgis EF. Timing of improvement after carpal tunnel release. *J Surg Orthop Adv*. 2004;13(4):206–209.
59. Gellman H, Kan D, Gee V, Kuschner SH, Botte MJ. Analysis of pinch and grip strength after carpal tunnel release. *J Hand Surg [Am]*. 1989;14(5):863–864.
60. MacDermid JC, Richards RS, Roth JH, Ross DC, King GJ. Endoscopic versus open carpal tunnel release: a randomized trial. *J Hand Surg [Am]*. 2003;28(3):475–480.