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## Original Research

## Trends in Nerve Transfer Procedures Among Board-Eligible Orthopedic Hand Surgeons



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**Purpose:** Enthusiasm for peripheral nerve transfers increased over the past several years, but further studies are still needed to establish the role of these procedures in peripheral nerve reconstruction. The primary goal of this study was to describe the frequency of nerve transfer surgery among newly trained orthopedic surgeons.

**Methods:** We queried the American Board of Orthopaedic Surgery Part II case log database for all nerve reconstruction Current Procedural Terminology codes for examination years 2004 to 2018 for surgeries performed between 2003 and 2017. Information collected for each patient included examination year, year of surgery, surgeon fellowship training subspecialty, geographic region (as defined by the American Board of Orthopaedic Surgery Part II case log database), patient age, and patient sex.

**Results:** A total of 3,359 nerve reconstruction cases were logged by 1,542 individual candidates from examination years 2004 to 2018. Of the nerve reconstruction codes, 2.1% were nerve transfer codes. There was a statistically significant increase in the proportion of nerve transfer codes over the study period, from 0% of nerve reconstruction codes in examination years 2004 to 2006 to 4.1% of nerve reconstruction codes in examination years 2016 to 2018 ( $Z = -6.82$ ;  $P < .001$ ).

**Conclusions:** There has been an increase in the number of nerve transfer procedures relative to all nerve reconstruction codes for peripheral nerve conditions.

**Clinical relevance:** There is a modest but significant increase in nerve transfer procedures over time among newly trained orthopedic surgeons, which suggests the need for long-term outcomes studies for nerve transfers procedures performed in the setting of peripheral nerve conditions.

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As nerve transfers have been shown to be a reliable and reproducible surgical option in the management of brachial plexus injury, their use has also increased in the management of more distal peripheral nerve injuries. A recent survey of the membership of the World Society of Reconstructive Microsurgery demonstrated that 88% of the 62 responding microsurgeons reported more frequent use of nerve transfers in the past 3 years of practice.<sup>1</sup> Compared with tendon transfers, end-to-end nerve repair, and

nerve grafting, nerve transfers preserve native muscle biomechanics, avoid surgery in the zone of injury, and can decrease the time and distance to muscle and sensory reinnervation.<sup>2</sup> For these reasons, they offer an appealing alternative or addition to existing reconstructive options.

Results from nerve transfers in patients with brachial plexus injury have been well-described over the past 2 decades,<sup>3–6</sup> and with these positive outcomes, enthusiasm for distal nerve transfers for isolated nerve palsies and injuries has increased. Because potential roles for nerve transfers have emerged in the setting of peripheral nerve injury and nerve transfers for this purpose have become more commonplace, further studies are needed to characterize the long-term outcomes of these procedures.

The primary goal of this study was to use the American Board of Orthopaedic Surgery (ABOS) case log database to determine the trend of nerve transfer surgery among newly trained orthopedic

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**Table 1**

International Classification of Diseases, Ninth Revision Codes for Peripheral Nerve Injuries

Brachial plexus injury	953.4
Lesion of brachial plexus	353.0
Injury to axillary nerve	955.0
Injury to median nerve	955.1
Injury to ulnar nerve	955.2
Injury to radial nerve	955.3
Injury to musculocutaneous nerve	955.4

surgeons over time, to determine whether a similar increase has occurred among this particular group. We hypothesized that there would be an increase over time in nerve transfer cases submitted as part of ABOS case logs.

## Materials and Methods

For this study, we analyzed deidentified administrative data from the ABOS Part II case log database for examination years 2004 to 2018, for surgeries performed between 2003 and 2017. The ABOS case log database consists of submitted case logs from a 6-month collection period from candidates undergoing the second part of the board certification process. Given the deidentified nature of the data, the study qualified for an exemption from our institutional review board.

Patients were identified by Current Procedural Terminology (CPT)-4 procedure codes for nerve grafting, nerve transfers, nerve repairs, and free functioning muscle transfers (Tables 1, 2). We specifically used CPT codes 64905 and 64907 to track nerve transfer procedures. This process is similar to strategies previously employed when identifying patients undergoing surgery for brachial plexus injury from administrative data sources.<sup>7,8</sup> We included patients regardless of the number of additional CPT-4 codes associated with them. Associated diagnostic codes for each patient were reviewed but were not used for case inclusion criteria owing to concerns for accuracy.<sup>9,10</sup> Case information collected included examination year, year of surgery, surgeon fellowship training, geographic region (as defined by the ABOS), patient age, and patient sex.

To assess the overall trends of surgical procedures for upper-extremity peripheral nerve conditions, we also accessed data from the Healthcare Cost and Utilization Project (HCUP), whose database, HCUPnet, collects hospital care data for the inpatient, ambulatory, and emergency department settings from 29 states. From the HCUPnet database, we conducted a search of ambulatory and inpatient surgeries performed for the treatment of ulnar nerve lesions (International Classification of Diseases, Ninth Revision [ICD-9] code 354.2), median nerve lesions (ICD-9 code 354.1), and radial nerve lesions (ICD-9 code 354.3) for 2012 and 2014, which were the only years available at the time of data collection.

## Statistical analysis

### Univariate analysis

The primary outcome was the presence of a nerve transfer code. Each CPT code for a nerve transfer procedure or other nerve reconstruction procedure was included in the calculation to account for multiple nerve surgery codes listed for a given surgical case. To determine whether there was a statistically significant difference in the proportion of nerve transfer codes over time, we used the Cochran-Armitage test for trends. For analysis, CPT codes were grouped by 3-year periods according to examination years: 2004 to 2006, 2007 to 2009, 2010 to 2012, 2013 to 2015, and 2016 to 2018.

Given the normal distribution of the surgeon geographic region, we used chi-square testing to examine the relationship between the proportion of nerve transfer codes relative to all nerve reconstruction codes and geographic region. For all statistical tests, significance was set at  $P < .05$ .

### Regression analysis

We performed logistic regression to examine the relationship between the dependent variable (surgeon-level proportion of nerve transfer codes relative to all nerve reconstruction codes) and the independent variables of year of examination and surgeon geographic region. Analysis at the surgeon level precluded the use of patient-level variables (such as patient age, patient sex, and anatomic region).

## Results

A total of 1,542 candidates logged a nerve reconstruction code from examination years 2004 to 2018. During this period, 3,359 cases were logged that contained a CPT code for a nerve reconstruction code (Table 3). The distribution of nerve reconstruction codes is listed in Table 4. Of all nerve reconstruction codes, 77 were nerve transfer CPT codes among 64 unique cases with at least one nerve transfer code (2.1%).

Among all nerve reconstruction cases, average age of patients was 38 years (range, 0–93 years) and 65% were male. Procedures were performed on 718 patients in the Northeast (21%), 661 in the Midwest (20%), 619 in the Southeast (18%), 561 in the Southwest (17%), 551 in the South (16%), and 229 in the Northwest (9%); 20 were not labeled to a specific region (1%).

Of the 64 cases containing at least one nerve transfer code, average age patients was 26 years (range, 0–76 years) and 81% were male. Procedures were performed on 6 patients in the Northeast (9%), 13 in the Midwest (20%), 16 in the Southeast (25%), 10 in the Southwest (16%), 16 in the South (25%), and 3 in the Northwest (5%). The 64 cases containing at least one nerve transfer code were performed by 37 unique candidates.

Of those 37 surgeons, 26 involved one nerve transfer case each; 5 involved 2 nerve transfer cases; 3 involved 3 nerve transfer cases; 2 involved 6 nerve transfer cases; and one involved 7 nerve transfer cases. All nerve transfers were performed by surgeons who reported completing a hand surgery fellowship.

Univariate analysis did not demonstrate a relationship between the presence of a nerve transfer code and geographic region. Trend analysis demonstrated a statistically significant increase in the proportion of nerve transfer codes over the study period; nerve transfers composed 0% of nerve reconstruction procedures in examination years 2004 to 2006 and 4% of nerve reconstruction procedures in examination years 2016 to 2018 ( $Z = -6.82$ ;  $P < .001$ ) (Fig. 1, Table 5). In regression analysis, examination year was a significant predictor of nerve transfer use (odds ratio = 1.275; 95% confidence interval, 1.179–1.379;  $P < .001$ ), but geographic region was not (odds ratio = 0.859; 95% confidence interval, 0.725–1.019;  $P = .081$ ).

The results of our search of the HCUPnet database revealed that the frequency of nerve procedures performed for ulnar, median, and radial nerve injuries increased 3.7%, 6.3%, and 10%, respectively, from 2012 to 2014 (Fig. 2).<sup>11</sup>

## Discussion

Our evaluation of ABOS Part II case log data demonstrated that the number of nerve transfer procedures relative to all nerve reconstruction codes for peripheral nerve conditions has increased. Most nerve reconstruction procedures were performed in the

**Table 2**  
Current Procedural Terminology—4 Codes for Brachial Plexus Injury and Traumatic Peripheral Nerve Injury Surgery

Neurorrhaphy procedures
64861 Suture of brachial plexus
64856 Suture of major peripheral nerve, arm or leg, except sciatic; including transposition
64857 Suture of major peripheral nerve, arm or leg, except sciatic; without transposition
64859 Suture of each additional major peripheral nerve
64872 Suture of nerve; requiring secondary or delayed suture
64874 Suture of nerve; requiring extensive mobilization, or transposition of nerve
64876 Suture of nerve; requiring shortening of bone
Neuroplasty procedures
64713 Neuroplasty, major peripheral nerve, arm or leg; brachial plexus
64708 Neuroplasty, major peripheral nerve, arm or leg; other than specified
Neurorrhaphy with nerve graft, vein graft, or conduit procedures
64892 Nerve graft (includes obtaining graft), single strand, arm or leg; $\leq 4$ cm long
64893 Nerve graft (includes obtaining graft), single strand, arm or leg; $>4$ cm long
64897 Nerve graft including harvest, multiple strands, arm, $\geq 4$ cm long
64898 Nerve graft including harvest, multiple strands, arm, $>4$ cm long
64901 Nerve graft, each additional nerve; single strand
64902 Nerve graft, each additional nerve; multiple strands
64905 Nerve pedicle transfer; first stage
64907 Nerve pedicle transfer; second stage

**Table 3**  
Nerve Surgery Case Characteristics (n = 3,359)\*

Demographic Characteristics	All Nerve Reconstruction Cases	Nerve Transfer Cases Only
Mean patient age, y	36 (23–50)	28.5 ( 1–41.3)
Sex, n (%)		
Male	2,191 (65.2)	52 (81.3)
Female	1,168 (34.8)	12 (18.8)
Geographic region		
Northeast	718 (21.4)	6 (9.4)
Midwest	661 (19.7)	13 (20.3)
Southeast	619 (18.4)	16 (25.0)
Southwest	561 (16.7)	10 (15.6)
South	551 (16.4)	16 (25.0)
Northwest	229 (6.8)	3 (4.7)
Other	20 (0.6)	0

\* Data represent median (interquartile range) unless otherwise noted.

**Table 4**  
Distribution of Nerve Reconstruction Codes (n = 3,704)

Nerve Reconstruction CPT Codes	Frequency (%)
64861 Suture of brachial plexus	16 (0.4)
64856 Suture of major peripheral nerve, arm or leg, except sciatic; including transposition	501 (13.5)
64857 Suture of major peripheral nerve, arm or leg, except sciatic; without transposition	853 (23.0)
64859 Suture of each additional major peripheral nerve	147 (4.0)
64872 Suture of nerve; requiring secondary or delayed suture	11 (0.3)
64874 Suture of nerve; requiring extensive mobilization, or transposition of nerve	18 (0.5)
64876 Suture of nerve; requiring shortening of bone	3 (0.1)
64713 Neuroplasty, major peripheral nerve, arm or leg; brachial plexus	125 (3.4)
64708 Neuroplasty, major peripheral nerve, arm or leg; other than specified	1,713 (46.2)
64892 Nerve graft (includes obtaining graft), single strand, arm or leg; $\leq 4$ cm long	34 (0.9)
64893 Nerve graft (includes obtaining graft), single strand, arm or leg; $>4$ cm long	21 (0.6)
64897 Nerve graft including harvest, multiple strands, arm, $\leq 4$ cm long	69 (1.9)
64898 Nerve graft including harvest, multiple strands, arm, $>4$ cm long	74 (2.0)
64901 Nerve graft, each additional nerve; single strand	14 (0.4)
64902 Nerve graft, each additional nerve; multiple strands	28 (0.8)
64905 Nerve pedicle transfer; first stage	77 (2.1)
64907 Nerve pedicle transfer; second stage	0

upper extremity; as expected, most orthopedic surgeons performing nerve reconstructions were hand and upper-extremity fellowship trained and took the hand and upper-extremity subspecialty exam.

Nerve transfers present viable options in the treatment of peripheral nerve injuries when end-to-end repair or nerve grafting is insufficient for the timely reinnervation of affected motor end plates.<sup>12</sup> The role of nerve transfers in the surgical reconstruction of

brachial plexus injuries is largely accepted; effective and reproducible results are reported to restore elbow flexion and shoulder abduction. Studies examining nerve transfers for elbow flexion and shoulder abduction demonstrated that patients achieved a Medical Research Grade of at least 3 for elbow flexion and shoulder abduction and external rotation without noteworthy donor nerve deficits.<sup>4–6</sup> Beyond their use in brachial plexus injuries, nerve transfers have gained popularity as an alternative to tendon

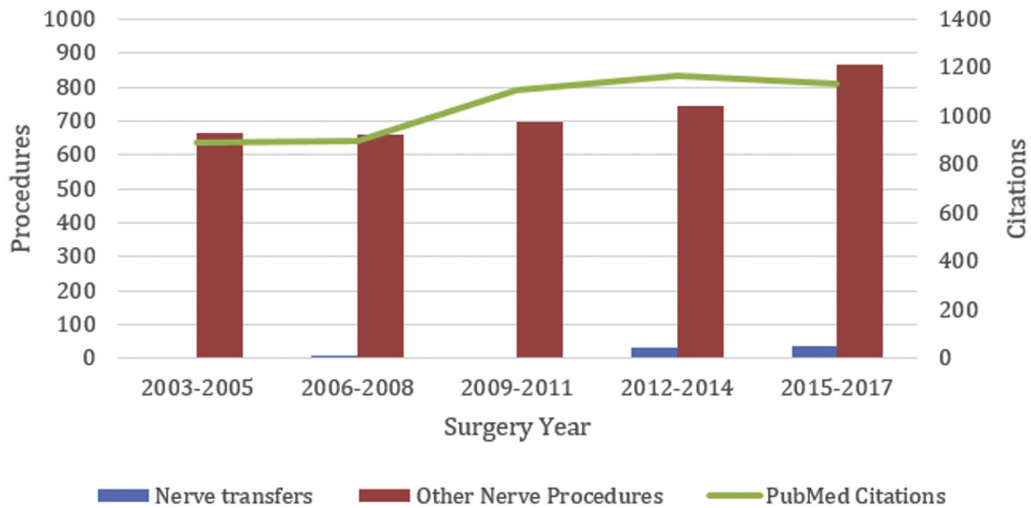


Figure 1. Number of nerve reconstruction procedures by surgery year and PubMed citations for the search term “nerve transfer” between 2013 and 2017.

Table 5  
Nerve Reconstruction Codes by Examination Year Group\*

Procedure Type	2004–2006	2007–2009	2010–2012	2013–2015	2016–2018	Total
Nerve transfers						
Frequency	0	7	3	30	37	77
Proportion	0.000	0.010	0.004	0.039	0.041	0.021
Other nerve reconstruction procedures						
Frequency	662	660	699	742	864	3,627
Proportion	1.000	0.990	0.996	0.961	0.959	0.979
Total	662	667	702	772	901	3,704

\* Data were determined using Cochran-Armitage trend test ( $Z = -6.8; P < .001$ ).

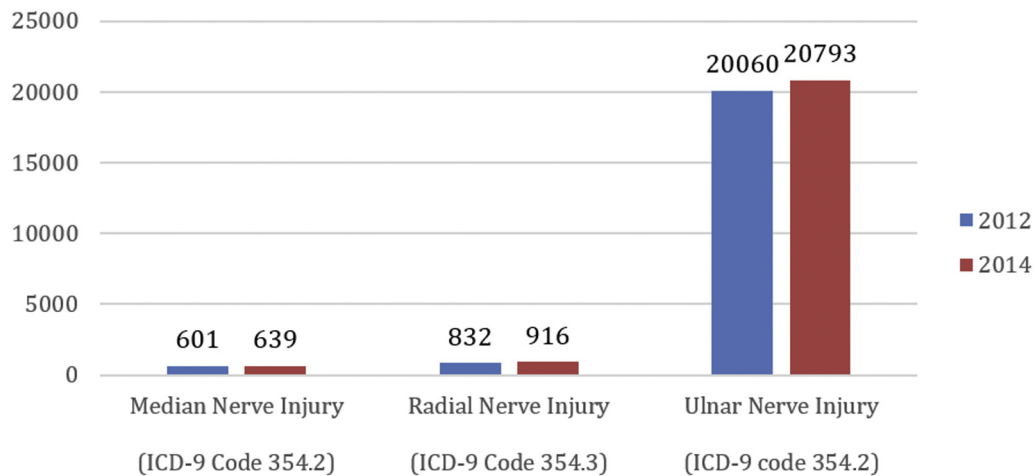


Figure 2. Frequencies of ambulatory and inpatient surgeries by nerve injury for 2012 and 2014.

transfers. More recently described end-to-end nerve transfers, such as the transfer of median nerve branches to radial nerve branches for radial nerve palsy and distal anterior interosseous nerve transfer to the ulnar nerve motor branch for complete, high ulnar nerve lesions, have shown promising results in early studies.<sup>13–16</sup> The supercharged end-to-side nerve transfer, in particular, which consists of distal anterior interosseous nerve transfer to the ulnar nerve as an augment in high ulnar nerve palsy, has gained momentum in the treatment of ulnar nerve pathology. This transfer

been used in the setting of trauma, but also for severe or recurrent cubital tunnel syndrome.<sup>17–20</sup> These successes have led surgeons to broaden indications for nerve transfers to include the treatment of radial nerve palsies, traumatic ulnar nerve injuries, and compressive neuropathy of the ulnar nerve.

The practice of nerve transfers for peripheral nerve injuries is relatively nascent compared with that for brachial plexus injury, and the outcomes of nerve transfers for peripheral nerve injuries remain variable compared with nerve grafts and tendon transfers.

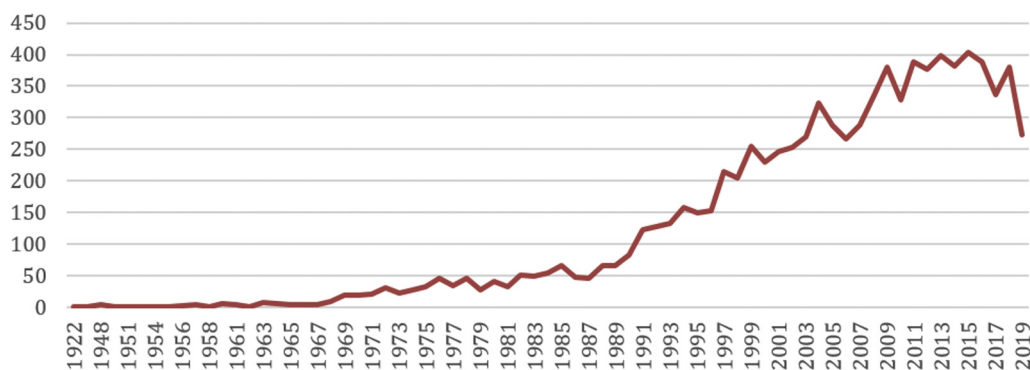


Figure 3. PubMed search results for the search term "nerve transfer," by year.

The heterogeneity in results after nerve transfers partly result from differences in surgeon decision-making when indicating a patient for a nerve transfer. The results of the current study demonstrate that newly trained orthopedic surgeons increasingly performed nerve transfers over the 14-year study period, but this increase was modest. The reason may be partly because of shortcomings of the current literature in defining indications for nerve transfers. Although a paradigm shift seems to have occurred within nerve reconstruction surgery, newly trained surgeons may be less likely to perform these procedures during their board collection period.

Our findings are also supported by overall trends in the number of surgeries performed for peripheral nerve injuries, which have also increased over time, as evidenced by our search of the HCUPnet database, which demonstrated increases in nerve procedures for median, ulnar, and radial nerve lesions. In addition, the increase in the relative number of nerve transfers performed parallels an increase in the number of citations for nerve transfer procedures that occurred in the past several years. The number of results in PubMed for the search term "nerve transfer" increased 24% from 270 to 336 between 2003 and 2017 during the same period as our study (Fig. 3).<sup>21</sup> With the data available, we are unable to determine whether the increased performance of peripheral nerve surgeries (seen in HCUPnet), the increase in nerve transfer cases submitted to ABOS (seen in our data), and the increased research publications for nerve transfer (seen in PubMed results) are related to an increased incidence of peripheral nerve injuries, increased surgeon familiarity or comfort with performing nerve transfers, or other factors. This is an area for future investigation.

There were limitations to this study. The absolute number of nerve transfers in this cohort was low, and the data set did not reflect the absolute rates of nerve transfers or nerve reconstruction procedures within the United States. Surgeon experience may also have a factor in the rates of nerve transfers in this cohort. Newly trained surgeons may avoid procedures that have less supportive outcome data until they are beyond their board collection period. In addition, these data do not reflect procedures that candidates may have performed in collaboration with a more senior surgeon. The data for this study also reflect only the practices of orthopedic surgeons and do not account for those of plastic surgeons or neurosurgeons, because the case log data from the American Board of Plastic Surgery and American Board of Neurological Surgery are unavailable for research purposes. Nevertheless, we expect that similar trends would be found among newly trained plastic surgeons and neurosurgeons. Moreover, the case log data for the Subspecialty Certificate in Surgery of the Hand (formerly the Certificate of Added Qualifications) examination were not included in

this analysis, nor are they available for research use. Still, the ABOS Part II case log database provides data that are rich with procedure specificity owing to the nature of how candidates must submit their case logs. The data also reflect the practices of surgeons across the entire United States and are not limited by region compared with state-level data sets.

Ultimately, this study quantified trends in nerve transfer surgery, providing insight into current practices of newly trained orthopedic surgeons: they are increasingly performing nerve transfer procedures, but at a slow rate. These results may reflect the slow adoption of these procedures in this surgeon population because of a need for further outcomes studies for nerve transfers in distal peripheral nerve injuries. More specifically, future studies are needed to examine patient-reported outcomes to evaluate the comparative effectiveness of different surgical techniques for nerve reconstruction and to identify reasons for variability in outcomes of nerve reconstruction surgery with the ultimate goal of guiding surgeons' decision-making for complex nerve injuries.

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