

# Surgically Treated Neuroma in Upper Extremity: Patient Characteristics and Factors Influencing Outcome of Surgery

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**Background:** Neuroma formation occurs after inappropriately or untreated nerve injuries. Patients surgically treated for neuroma were characterized and factors influencing outcome evaluated.

**Methods:** In a retrospective observational study, data from medical records of patients surgically treated for neuroma in two Swedish regions were analyzed.

**Results:** In 115 included patients (median age at surgery 45 years [IQR 29–55]), 55% (62/115) were men and 49% (56/115) were manual laborers. Most affected nerves were in hand or lower forearm (76/115, 66%). Smoking habits, affected nerves, and cause/mechanism(s) of injury differentiated the sexes. More motor nerve injuries were observed among women and more mixed nerve injuries among men. Iatrogenic injuries, such as injury to superficial sensory radial nerve or thenar branch of median nerve, more frequently affected women (27/52, 52%). Pain, the dominant preoperative symptom, improved after surgery. Overall, surgery cured/improved 79 of 115 (69%) patients. Patients treated with repair or reconstruction (n = 62) were younger than patients given neuroma transpositions (n = 43) and sensory nerve injuries were more often treated by transposition. No difference in outcome was observed concerning patient characteristics or surgical methods. Most patients had one surgery (102/115, 89%). No specific risk factors for a re-operation could be identified, but need for re-operation(s) was associated with poor outcome, even after repeated surgery.

**Conclusions:** Patients with a neuroma benefit from surgery with significantly reduced pain, but symptoms may remain. Surgical method does not affect outcome. Preventing neuroma formation is crucial, presently highlighted in a high frequency of iatrogenic injuries, especially among women. (*Plast Reconstr Surg Glob Open* 2022;10:e4076; doi: 10.1097/GOX.0000000000004076; Published online 31 January 2022.)

## INTRODUCTION

Neuroma may be a result of a partial or complete,

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acute or chronic nerve injury,<sup>1,2</sup> and commonly affects hand and upper extremity.<sup>2,3</sup> Where motor nerves are affected, extensive functional disability is observed among patients.<sup>4–6</sup> The bulb-shaped thickening of the proximal nerve-end with abnormal and unorganized growth of nerve fibers is created by inappropriately repaired or unrepaired nerve injuries<sup>1,7</sup> and may be due to absence of a distal nerve-end, forming an end neuroma. Another type is

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neuroma-in-continuity, which appears after a partial nerve injury, partial recovery from a nerve injury or after repair or reconstruction of an injured nerve. Neuroma pain can also occur by scar-tethering of the nerve.<sup>2</sup>

Various treatment options exist for neuromas, ranging from medical to surgical strategies, but the latter, consisting of active or passive approaches,<sup>3,5,8,9</sup> offer the most advantageous outcome. Repair or reconstruction of the nerve injury, if possible, provides the only curative treatment.<sup>5</sup> However, further studies are warranted to explore treatment options concerning neuropathic pain.<sup>10</sup> Follow-up studies could provide tools to determine which specific interventions would be most effective for whom.<sup>11</sup> Current consensus supports use of active over passive approaches. Active techniques involve repair and reconstruction of the nerve; the latter being done with either autografts, allografts, or a conduit to bridge the defect; all intended to connect the proximal nerve-end with the distal nerve-end.<sup>3,5,8,9</sup> Passive surgical techniques, including excision of neuroma and implantation into muscle, bone and conduits without a distal nerve-end, or a nerve cap, are used when the active approach is not possible or not preferred.<sup>2</sup> Another technique employed, for example in a neuroma-in-continuity, is to wrap or bolster a neuroma-in-continuity or a tethered scarred nerve, using soft tissue, such as fat, muscle, or a pedicled or free flap, around or above the neuroma to give protection and cover.<sup>12</sup> Nerve capping, using various materials, has been introduced and may reduce expression of pain markers.<sup>3</sup> A recently introduced passive method recommends using a nerve allograft without any distal nerve-end attached, which allows axons to grow “blind.”<sup>13,14</sup>

To summarize, although various surgical methods can be explored, no surgical gold standard of treatment has been identified.<sup>15</sup> New techniques may improve outcome in neuroma treatment, but absence of studies comparing different methods is a limiting factor.<sup>3</sup> Therefore, treatment of a neuroma has been, and remains, an important field for research. Our aim was to characterize patients treated surgically for neuroma in the upper extremity and to evaluate both treatment options and factors influencing surgical outcome.

## MATERIAL AND METHODS

Patients surgically treated for a defined neuroma in the upper extremity from January 1st 2008 to June 30th 2020 at the Department of Hand Surgery, Plastic Surgery and Burns, Linköping University Hospital and at the Department of Hand Surgery, Skåne University Hospital, Malmö-Lund were identified and included. Data were collected from medical records by two medical students (ED and HG) and analyzed retrospectively. Background data, surgical method, and outcome were registered. The professional tasks of each patient were carefully evaluated and judged as either nonmanual or manual labor. Symptoms and clinical examinations preoperatively, postoperatively, and at long-term follow-up were documented. The surgeon’s and therapist’s documentation in the patient folder, pre- or postoperatively or long-term, based on

## Takeaways

**Question:** What characterizes patients with neuroma and what influences outcome of neuroma surgery?

**Findings:** This retrospective observational study shows that men and smokers are overrepresented among surgically treated patients with neuroma. Digital and superficial sensory radial nerves are mostly affected. Pain, the dominant symptom, significantly improves by surgery, but symptoms still persist. Different surgical methods, being nerve repair/reconstruction or nerve transposition, or other patient characteristics, do not affect outcome. Iatrogenic injuries frequently affect women. A re-operation increases the risk for poor outcome.

**Meaning:** This study reveals that preventing neuroma formation, particularly iatrogenic nerve injuries, is crucial, but surgery is worthwhile!

history taken from the patient in combination with clinical examinations (eg, muscle strength and various modalities of sensibility), was used to grade outcome at the last visit. A four-degree measurement scale was applied, including the categories cured, improved, unchanged, and worsened.

## Statistics

Variables are presented as the median [IQR 25–75] and numbers (n/n, %). The Mann-Whitney U-test was used to compare groups. Chi-squared tests (independent groups; or Fisher’s exact test if a group had  $n < 5$ ) and McNemar’s test (paired samples) were used for comparisons between groups. The four-grade category outcome system was combined into two groups: cured and improved versus unchanged and worsened. A binary multiple logistic regression was carried out to analyze the association between the independent variables sex, age at surgery, smoking, comorbidity, injured nerve, surgical methods, and whether or not there was a re-operation and the dependent variable final outcome. To analyze risk factors for patients needing a re-operation, a binary multiple logistic regression was done using the independent variables sex, age at surgery, smoking, comorbidity, injured nerve, and surgical methods. Significant *P*-values were set at less than 0.05.

Ethical approval was given by the Swedish Ethical Review Authority (registry number 2020-01484 0617; no informed consent needed from subjects). The study conforms to the Helsinki Declaration.

## RESULTS

### Characteristics

During the study period of 12.5 years, 115 patients were surgically treated for neuroma at two hand surgery units in Sweden [total catchment population of around 3 million people (2020)]. Patient background characteristics and type of injured nerve, cause/mechanism(s) of injury, and type of surgery are described in [Tables 1](#) and [2](#)

**Table 1. Background Characteristics of Patients Surgically Treated for a Neuroma in the Upper Extremity**

	Total Population (n = 115)	Men (n = 63)	Women (n = 52)	P (Sex)
Sex (women/men)	52/63 (45/55)	NA	NA	NA
Age at surgery (y)	45 [29–55]	43 [26–55]	45 [30–57]	0.578
Smokers	30 (26)	21 (33)	9 (17)	<b>0.045</b>
Somatic comorbidity				
Yes	48 (42)	25 (40)	23 (44)	0.623
No	67 (58)	38 (60)	29 (56)	
Psychiatric comorbidity				
Mental illness/abuse	13 (11)	5 (8)	8 (15)	0.246
Profession				
Manual laborer	56 (49)	34 (54)	22 (42)	0.393
Non-manual laborer	21 (18)	11 (18)	10 (19)	
Unemployed	3 (3)	3 (5)	0 (0)	
Sick leave	1 (1)	0 (0)	1 (2)	
Early retirement	2 (2)	1 (2)	1 (2)	
Retired	12 (10)	5 (8)	7 (14)	
Unknown	20 (17)	9 (14)	11 (21)	
Symptom duration until first visit to a hand surgery unit (mo)	1 [0–12]	1 [0–19]	2 [0–12]	0.634
Time from surgery to last visit (mo)	6 [3–15]	4 [3–14]	8 [3–18]	0.375

Values are median [IQR 25–75] or n (%). P-values based on Mann-Whitney U-test or chi-squared or Fisher exact test (if less than five samples per group). Somatic comorbidity in all patients: Cardiovascular disease n = 26 (23); musculoskeletal disease n = 16 (14); systemic disease n = 14 (12); diabetes n = 6 (5); cervical pathology n = 1 (1); others (ie, asthma chronic obstructive pulmonary disease, liver disease etc.) n = 11 (10); multiple diseases n = 21 (18).

P-values in bold indicates significantly higher frequency of smokers among men.

and in Supplemental Digital Content 1. (See tables, Supplemental Digital Content 1, which display [a] Type of nerve, level of injury, and mechanism/cause of injury. [b] Characteristics, presence of pain before and after surgery and outcome in patients with surgically treated neuroma in the digital nerve or the superficial sensory branch of the radial nerve. [c] Characteristics of patients, surgical methods, reason for re-operation and outcome in patients re-operated and not re-operated for neuroma. <http://links.lww.com/PRSGO/B902>.)

Median age at surgery was 45 years [29–55] with no significant difference between the sexes. Men were more frequent smokers, had an injury to a mixed nerve, had a nerve injury due to an amputation, and were injured as a result of manual activities outside home. Women had more motor nerve injuries and fewer mixed nerve injuries. The

damage mechanism in female patients was mostly nerve transection (51/52, 98%), where the cause was frequently defined as iatrogenic (27/52, 52%). Common causes that were equally distributed between women and men were injuries related to home equipment, whereas manual activities outside home were frequently seen as a cause among men (21/63, 33%). There were no significant sex differences regarding comorbidity, injured nerve, level of injury, type of surgery, profession, or occurrence of re-operations. Symptom durations up to the first visit to a hand surgery unit are presented in Table 1 and Supplemental Digital Content 2. (See figure, Supplemental Digital Content 2, which displays frequencies in numbers for [a] symptom duration up to first visit to a hand surgery unit and [b] time from surgery to last visit expressed in months. <http://links.lww.com/PRSGO/B903>.)

**Table 2. Type of Nerve and Type of Surgery**

	Total Population (n = 115)	Men (n = 63)	Women (n = 52)	P(Sex)
Type of nerve				
Sensory	91 (79)	50 (79)	41 (79)	<b>0.014*</b>
Motor	8 (7)	1 (2)	7 (14)	
Mixed	16 (14)	12 (19)	4 (8)	
Type of neuroma found at surgery				
End neuroma	98 (85)	52 (82)	46 (88)	0.373
Neuroma-in-continuity	17 (15)	11 (18)	6 (12)	
Type of surgery				
Transposition	38 (33)	21 (33)	17 (33)	0.629
Transposition with conduit	5 (4)	1 (2)	4 (8)	
Repair	16 (14)	7 (11)	9 (17)	
Repair with conduit	11 (10)	7 (11)	4 (8)	
Reconstruction with autologous graft (PIN)	22 (19)	14 (22)	8 (15)	
Reconstruction with autologous graft (sural nerve)	12 (10)	6 (10)	6 (12)	
Reconstruction with allograft	1 (1)	1 (2)	0 (0)	
Decompression	3 (3)	1 (2)	2 (4)	
Coverage with flap	7 (6)	5 (8)	2 (4)	
Re-operation				
Yes	13 (11)	7 (11)	6 (12)	0.943
No	102 (89)	56 (89)	46 (88)	

Values are median [IQR 25–75] or n (%). P-values based on Mann-Whitney U-test or chi-squared or Fisher exact test (if less than five samples per group).

\*Significantly more motor nerve injuries among women and mixed nerve injuries among men.

In relation to the whole study population, the most frequent nerves with neuroma were digital nerves (sensory nerves) (49/115, 43%), followed by the superficial radial nerves (27/115, 24%). Therefore, most of the neuromas were found in sensory nerves located in lower forearm, wrist and hand.

**Surgical Methods**

Most patients were treated with reconstruction or repair of a nerve with nerve suture, with or without a conduit or graft, if a distal nerve-end was accessible (active method, n = 62) (Tables 2 and 3). If there was no distal nerve-end, transposition of the end neuroma, with or without capping, was performed (passive method, n = 43). For neuroma-in-continuity, decompression, wrapping, or covering with soft tissue were performed (n = 10). No sex differences were observed between so-called passive surgical methods, such as transpositions, and active methods, including nerve repair and nerve reconstruction (Table 2).

**Outcome of surgery**

Among all patients, time from surgery to last follow-up was 6 [3–15] months (Table 1; Supplemental Digital Content 2, <http://links.lww.com/PRSGO/B903>). Generally, preoperative pain was the most dominant symptom and significantly improved by neuroma surgery, irrespective

of surgical method (Tables 3, 4) (Supplemental Digital Content 1b, <http://links.lww.com/PRSGO/b902>). Outcome of surgery was graded by most patients at the last visit as cured/improved [79/115 (69%)], with 36 of 115 (31%) grading it as unchanged/worsened (SDC1b,c presented for digital and superficial sensory radial nerves as well as for transpositions and repair/reconstructions, respectively). No significant sex difference in outcome could be detected ( $P = 0.271$ , data not shown).

In the digital nerve injury group, 37 of 49 (76%) patients were cured/improved compared with 16 of 27 (59%) among superficial sensory radial nerve injuries, with no significant difference in outcome (Supplemental Digital Content 1b, <http://links.lww.com/PRSGO/B902>). Patients with a digital nerve injury differed from those with a superficial sensory radial nerve injury concerning cause of injury, with more injuries caused by home equipment, while more iatrogenic injuries were seen among the superficial sensory radial nerves. The groups also differed regarding surgical method as more nerve reconstructions were used for the digital nerves, whereas transpositions, flaps, and decompressions were used for superficial sensory radial nerves. Irrespective of type of nerve, pain was reduced by surgery.

Concerning type of surgery and outcome, there was no significant difference between passive and active surgical methods (Table 3). Among 43 patients with a neuroma

**Table 3. Patient Characteristics and Outcome, based on a Four-grade Scale, of Patients with Neuroma Surgically Treated with Either Nerve Transposition with or without Conduit (Passive Method) or Nerve Repair/Reconstruction with or without Graft (Active Method)**

	Transposition (n = 43)	Repair or Reconstruction (n = 62)	P
Sex			
Women	21 (49)	27 (44)	0.593
Men	22 (51)	35 (56)	
Age at surgery (y)	51 [34–59]	38 [26–53]	<b>0.020</b>
Smokers	13 (30)	15 (24)	0.362
Type of nerve			
Sensory	42 (98)	31 (66)	<b>0.0001*</b>
Motor	0 (0)	8 (13)	
Mixed	1 (2)	13 (21)	
Damage mechanism			
Nerve transection	33 (77)	62 (100)	<b>&lt;0.0001†</b>
Amputation	7 (16)	0 (0)	
Crush injury	3 (7)	0 (0)	
Cause of nerve injury			
Iatrogenic	25 (58)	14 (23)	<b>0.001‡</b>
Home Equipment	6 (14)	28 (45)	
Manual activities outside home	10 (23)	14 (23)	
Animal bite	1 (2)	2 (3)	
Explosion	0 (0)	3 (5)	
Self-injury	1 (2)	1 (2)	
Pain (pre/post)			
Yes	40 (93) / 17 (40)	43 (69) / 29 (47)	0.366/0.118
No	1 (2) / 22 (52)	4 (7) / 19 (31)	<b>&lt;0.0001§</b>
Missing	2 (5) / 4 (9)	15 (24) / 14 (23)	
Outcome			
Cured/improved	33 (77)	40 (65)	0.181
Unchanged/worsened	10 (23)	22 (35)	
Time from first surgery until last visit (mo)	4 [3–14]	6 [3–18]	0.391

Values are median [IQR 25–75 percentile] or n (%). P-values based chi-squared test or Fisher exact test (if less than five samples per group), Mann-Whitney U-test and McNemar's exact test (pre/post; paired samples).

\*Motor and mixed nerve injuries were significantly more common among repair/reconstructions than among transpositions.

†Amputation and crush injuries were significantly more common among transpositions than among repair/reconstructions.

‡Iatrogenic injuries as cause were significantly more often seen among transpositions and home equipment injuries were significantly more often seen among repair-reconstructions.

§P-value between pre- and postsurgery.

**Table 4. Preoperative Symptoms versus Symptoms at the Last Visit in Patients with Surgically Treated Neuroma in the Upper Extremity**

	Total Population Preoperative/ Postoperative	P-values (Preoperative– Postoperative)
Pain		
Yes	92 (80) / 54 (47)	<0.0001
No	5 (4) / 41 (36)	
Missing data	18 (16) / 20 (17)	
Paraesthesia		
Yes	33 (29) / 13 (11)	1.0
No	4 (4) / 2 (2)	
Missing	78 (68) / 100 (87)	
Sensory loss		
Yes	86 (75) / 63 (55)	0.063
No	3 (3) / 8 (7)	
Not applicable	8 (7) / 8 (7)	
Missing	18 (16) / 36 (31)	
Motor loss		
Yes	23 (20) / 23 (20)	NA
No	0 (0) / 0 (0)	
Not applicable	90 (78) / 86 (75)	
Missing	2 (2) / 6 (5)	
Palpable neuroma		
Yes	38 (33) / 3 (3)	0.063
No	5 (4) / 7 (6)	
Missing	72 (63) / 105 (91)	

Values are median [IQR 25–75 percentile] or n (%). P-values based on McNemar's exact test (preoperative/postoperative; paired samples). NA = not applicable.

transposition, n = 33 (77%) were cured /improved and among 62 patients with a repair/reconstruction, n = 40 (65%) were cured/improved; no difference observed ( $P = 0.181$ ). Patients treated using an active surgical method were significantly younger (age at surgery 38 years [26–53]) than those treated using a passive surgical method (51 [34–59]) ( $P = 0.020$ ); the type of nerve in the older group was more often motor or mixed, and nerve transections as well as home equipment injuries were more common. A significant difference was seen between presence of pain before and after surgery in both types of surgery. Presence of pain at the last visit and re-operation were more frequent in the group with a worsened/unchanged outcome ( $P < 0.0001$  and  $P = 0.013$ , respectively, data not shown). Time from first surgery until last visit showed that the unchanged/worsened group had the longest follow-up time (median 16 [7–29] months compared with 3 [3–12] in the cured/improved group) ( $P = 0.0001$ ). No other changes were seen (data not shown).

Characteristics of the patients needing one or more re-operation(s), compared with the single operation population, are presented in Supplemental Digital Content 1c (<http://links.lww.com/PRSGO/B902>). Re-operation occurred significantly more often after decompression, soft tissue coverage or use of flap as the primary surgical method, compared with when repair/reconstruction was used ( $P = 0.021$ ). Outcome was another factor that exhibited a disparity, where the situation of the re-operated patients was more likely to be unchanged/worsened at the last follow-up compared with a single surgical procedure ( $P = 0.013$ ). Time from first surgery up to last visit was significantly longer in the re-operated group ( $P < 0.0001$ ). The most common reason for re-operation was pain with transposition of the neuroma or covering with a flap as

the surgical technique. No other factors differed between the groups. Thirteen patients had one re-operation (n = 13/115, 11%), six of 115 (5%) had two, and four of 115 (3%) had three re-operations.

The surgical methods in the two evaluated regions changed over time. Transposition and nerve repair are used for the last decade, whereas new techniques, such as nerve reconstruction with nerve allograft, have recently been introduced (data not shown).

#### Regression Analyses

No association between surgical method, age at surgery sex, smoking, or comorbidity, injured nerve, and final outcome of surgery could be revealed. However, there was a significant association between having a re-operation and poor outcome (unchanged/worsened; Exp (B) 0.217, CI 95% [0.063–0.748],  $P = 0.007$ ), indicating that not having a re-operation meant a five-fold increase in the chance of being cured/improved at last follow-up. No specific risk factors for a re-operation could be identified.

## DISCUSSION

Overall, patients benefit from surgery for neuroma even though most still may have rather severe residual symptoms at long-term follow-up. If the result is poor after the first surgery, the final outcome is even worse despite repeated surgery.

The percentage of secondary surgeries has been stated earlier in the literature to be around 8% and 6%, which is quite similar to the present finding of 11%.<sup>8,16</sup> In our study, median time from first surgery to re-surgery was 14 months, being similar to previously reported (16 months).<sup>8</sup> We found that the most common cause for re-operation is pain, which is in line with previous studies.<sup>8</sup> Transposition of a neuroma, as in our study, is frequently used as a surgical technique during re-operation.<sup>8,17</sup> Relief of pain and outcome after re-operation have been discussed in the literature and indicate that no one method is more effective than another.<sup>17</sup> From a global view of neuroma treatment, pain improves by surgery, but the present regression analysis did not identify any specific risk factors for a re-operation. In addition, due to the limited number of patients with a second and third re-operation, we cannot create an algorithm for management of patients with persistent pain after the first re-operation, but the surgeon has to consider the spectrum of surgical options, if further surgery ever is warranted, and probably in collaboration with a pain clinic.

The total number of patients treated surgically for neuroma at our hand surgery units studied, and probably at many other units, is low, but these patients require many outpatient visits with rehabilitation and long follow-up. The present patient characteristics are similar to those previously published.<sup>6,8,16,18,19</sup> A greater proportion of our population smoked (26%, age 13–88 years) in relation to the Swedish society in general (7%, age 16–84, 2018; data from the Public Health Authority<sup>20</sup>). The data, with a higher portion of smokers, support earlier knowledge about peripheral nerve injuries and smoking, where

smoking does not positively promote healing of nerve tissue and augments risks for complications, particularly pain.<sup>21,22</sup> In our data, most patients are of working age, and men are slightly overrepresented. Interestingly, women, had more iatrogenic nerve injuries, whereas for men the leading sources of injuries were professional tools and manual activities outside the home. The latter may reflect the professions and home activities of men and women, respectively. Men are often injured when working with sharp tools that can potentially cause the described variety of hand and nerve injuries. Men had more amputations than women, which can be explained by their differing professions. However, this may indicate that damage mechanism and cause of injury are related.<sup>23</sup>

The sensory nerves are the most frequent type of nerve to be injured with a subsequent symptomatic neuroma formation, which may be due to their superficial anatomical position and risk of pain.<sup>18</sup> The superficial sensory radial nerve may be particularly at risk of sustaining a traumatic or an iatrogenic injury.<sup>24</sup> Moreover, injuries to the thenar branch of the median nerve may have an iatrogenic cause, connected to carpal tunnel surgery and surgery for a radio-volar ganglion, as reported.<sup>2,25</sup> Neuroma of the superficial sensory nerves may be more frequently transposed, in contrast to motor and mixed nerves, due to their location and function.<sup>16</sup>

Several factors influence the choice of surgical method; condition of the injured nerve and accessibility of a distal nerve-end may be two of them.<sup>3</sup> Transposition into bone, vein, muscle, soft tissue, or fat is chosen in the absence of a distal nerve-end. The technique is well-proven with a long track record compared with other techniques. One disadvantage with this passive technique is the possibility of re-formation of neuroma, since the nerve continues to regenerate without a target.<sup>3</sup> One interesting aspect is the success rate of transposition surgery, despite no function being gained,<sup>26</sup> indicating that the efficiency of transpositions is most probably related to the observed pain relief. Transpositions have been shown not just to reduce pain, but also to enhance quality of life and reduce risk for depression in the patients.<sup>4</sup>

An identifiable distal nerve-end allows nerve reconstruction or end-to-end nerve repair.<sup>3</sup> Patients in the repair/reconstruction group were younger. One may relate the indication for surgery to age and possibilities for subsequent outcome. The brain's capacity and plasticity are superior in young adults and children compared with an elderly population, which may generate a better outcome for sensory function.<sup>5,27</sup> The inherent regenerating capacity of motor nerves, and their probably less important non-misdirecting recovery, may enhance outcome for motor function after repair and reconstruction. All present neuromas in motor nerves were found in the reconstruction or repair group, and surgery was performed to gain function and not to treat pain. In accordance with earlier literature, the present minor nerve injuries, such as to digital nerves or superficial sensory branches of the radial nerve, were surgically treated with autografts, for example terminal branch of the posterior interosseous

nerve (PIN), transposition, or excision and repair.<sup>6</sup> This is in contrast to major nerve injuries, which, if a primary suture was not possible, were more often treated with sural nerve autografts or, if a very short nerve gap was present, bridging with a nerve conduit.<sup>5,28</sup> One published article indicates that nerve repair is a superior technique compared with transposition, which is in contrast to the present study, where transposition of a neuroma exhibited an acceptable outcome.<sup>29</sup>

According to previous literature, surgical methods have changed over the years, meaning that nerve allografts and nerve conduits are used nowadays. However, older and well-proven techniques are still valuable, such as excision and direct repair of the nerve, neuroma transposition, and autologous nerve grafting. The technique with a flap covering the neuroma is also still, but not frequently, used. The method is especially applicable in more difficult cases, where the neuroma is in continuity and a covering is needed.<sup>12,30</sup> However, most importantly, the surgical methods must be selected based on injury conditions, the affected nerve and its location.

The limitation of this study is the lack of continuity regarding the patients' last visit, which does not allow for any detailed analysis of subsequent symptom relief. There was no controlled and detailed examination of various functions at the same point in time. The symptoms were described subjectively from the view of the surgeons and therapists, entailing a risk of bias. Furthermore, there is a lack of data concerning pre- and postsurgery symptoms. However, there were sufficient data concerning pre- or postoperative pain to allow analysis, which showed a clear improvement concerning number of patients with pain relief.

A neuroma is a complex condition, resulting in severe pain with reduced quality of life. Most of the patients improved and had less pain after surgery, but with enduring symptoms. No significant relation was seen between factors such as sex, age at surgery, smoking, comorbidity, surgical method, or injured nerve and outcome. The need for re-operation indicated a higher risk that final outcome would be impaired. The high frequency of iatrogenic injuries, especially among women, needs to be highlighted. Prevention of neuroma formation is crucial, but care and attention during surgical interventions may reduce the risk for nerve injuries.

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