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CLINICAL ARTICLE

Common peroneal nerve schwannomas around the knee: a surgical case series of 44 patients and systematic review of the literature

Godard C. W. de Ruiter, MD, PhD,[1,2] Kirsten M. Hayford, RN, MSN,[2] Thomas F. H. Vissers,[3] and Robert J. Spinner, MD[2]

[1]Department of Neurosurgery, Haaglanden Medical Center, The Hague, The Netherlands; [2]Department of Neurosurgery, Mayo Clinic, Rochester, Minnesota; and [3]Medical Library, Haaglanden Medical Center, The Hague, The Netherlands

OBJECTIVE Resection of common peroneal nerve (CPN) schwannomas is generally believed to be associated with a high risk of postoperative deficit, especially the chance for development of a foot drop. The goal of this study was to investigate the surgical results for resection of schwannomas from the CPN around the knee and specifically the chance of developing a postoperative motor deficit.

METHODS Data from 36 patients with sporadic schwannomas and 8 patients with schwannomatosis (12 schwannomas total) treated at two centers were retrospectively analyzed. For sporadic cases, different locations around the knee were compared (i.e., proximal to the fibular head [FH], at the FH, and distal to the FH), taking into account the preoperative duration of symptoms, size at presentation, and surgical results of resection. The literature was systematically reviewed for reported cases by searching the PubMed and Embase databases.

RESULTS A total of 24 schwannomas proximal to the FH were surgically treated: 11 at the FH, and 13 distal to the FH. For the entire cohort, the mean size of CPN schwannomas distal to the FH at presentation was smaller (1.4 × 1.8 cm) compared with those proximal to (2.0 × 2.2 cm) and at (2.2 × 2.3 cm) the FH, although these differences were not statistically significant. The mean preoperative duration of symptoms was slightly longer for schwannomas distal to the FH (35 months) than for those proximal to the FH (21 months) and at the FH (27 months); however, this difference was not significant. Postoperative deficits occurred in 3 sporadic cases: 2 patients with temporary weakness (Medical Research Council grade 4) that completely resolved within several months and 1 patient who had previously undergone surgery elsewhere and presented with deficits and in whom weakness increased after resection. Improvement in preoperative deficits was observed in 1 patient with extensor hallucis longus muscle paralysis that completely recovered. One patient with schwannomatosis developed muscle weakness after resection of a plexiform schwannoma. A systematic review of 21 previously reported cases in the literature showed that larger CPN schwannomas (> 5 cm) were more likely to result in permanent motor deficits.

CONCLUSIONS This retrospective study of 44 patients shows that peroneal nerve schwannomas around the knee can be safely removed with a low risk of deficits. The systematic review of the literature suggests that larger schwannomas are more likely to result in permanent deficit. In the authors' opinion, CPN schwannomas can best be resected, preferably when the lesion is relatively small.

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KEYWORDS fibular; lateral popliteal; nerve sheath tumor; neurinoma; enucleation; resection; peripheral nerve; surgical technique

Schwannomas can occur anywhere in the body, with a predilection for extremities. There are several treatment options: follow-up with MRI, biopsy, or resection. Surgical procedures include en bloc resection, extracapsular enucleation of the schwannoma, or intracapsular piece-meal resection.[1,2] Generally, if a larger nerve is affected, consisting of several fascicles, resection from the pseudocapsule, while leaving the true capsule intact, is the preferred procedure. This technique has been called "enucleation,"[1,3,4] but other authors have

ABBREVIATIONS CPN = common peroneal nerve; EHL = extensor hallucis longus; FH = fibular head; MRC = Medical Research Council; NF2 = neurofibromatosis type 2; PL = peroneus longus; TA = tibialis anterior.

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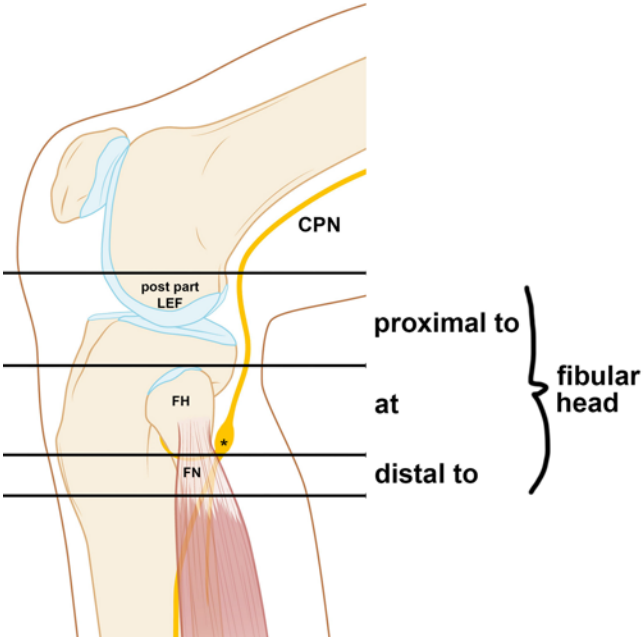

FIG. 1. Anatomical illustration of the different zones for potential locations of CPN schwannomas around the knee. The zones were determined on sagittal MRI scans of the knee. Lesions proximal to the FH were located between the upper border of the posterior part of the lateral epicondyle of the femur (LEF) and the apex of the FH, those at the FH are located between the apex of the FH and the start of the fibular neck (FN), and those distal to the FH are located at the fibular neck. In this case the schwannoma (*asterisk*) is located in the zone at the fibular head. © Godard de Ruiter, published with permission.

referred to this technique as "intracapsular resection,"[5,6] which can be a confusing term because the true capsule is preferably left intact. During this procedure the epineurium is opened in the length of the nerve over the site of the lesion. Subsequently, the pseudocapsule, which frequently also contains normal fascicles, is carefully dissected from the true capsule that surrounds the tumor. The fascicle from which the schwannoma originated is identified, and if there is no response to bipolar stimulation, this fascicle is transected proximally and distally to the tumor so the lesion can be removed in toto without damaging the normal nerve fascicles.[2] Sometimes, however, if the tumor is too large to remove with this technique, internal debulking is first performed before the tumor and capsule are resected from within the pseudocapsule.

Even in experienced hands the procedure for resection of schwannoma described above can result in postoperative deficits, most frequently sensory disturbances (from manipulation of the nerve during tumor resection and possibly due to transection of the originating tumor fascicle), but sometimes also muscle weakness.[7] Schwannomas affecting the common peroneal nerve (CPN) are often believed to be highly vulnerable for postoperative deficits following resection and specifically for the development of a foot drop.[3,8] During counseling for surgery, patients are informed about this possibility, but based on the current literature of a few case reports and one recent small series, it is not possible to give a percentage for the risk of developing this complication.

The goal of this study was to investigate the surgical results for a large cohort of patients with a sporadic schwannoma in the CPN localized around the knee. In addition to the overall results for surgery, subgroup analysis was performed for different locations around the knee, namely proximal, at, and distal to the fibular head (FH; Fig. 1). The reason for this analysis was that especially for the distal site (a known compression site of the CPN) we suspected that the preoperative duration of symptoms might differ, as well as the size of the tumor at presentation, which could both affect the preoperative chance for weakness and development of neurological deficits after resection. In addition, we investigated results for resection of CPN schwannomas in the case of schwannomatosis and we systematically reviewed the current literature on CPN schwannomas, specifically to investigate reported sizes of CPN schwannomas and the development of postoperative deficits.

Methods

All patients who were surgically treated for a CPN schwannoma by the senior author (R.J.S.) at the Mayo Clinic between 2007 and 2024 or by the first author (G.C.W.d.R.) at the Haaglanden Medical Center between 2014 and 2024 were included. Sporadic cases of CPN schwannomas were analyzed separately from those with multiple schwannomas that were either neurofibromatosis type 2 (NF2) related or non-NF2 related. Cases of neurofibromas and/or neurofibromatosis type 1 involving the CPN were excluded. Cases that involved the separate peroneal branches (either deep or superficial) distal to the fibular neck or the peroneal nerve/division within the sciatic nerve in the thigh (cranial to the lateral epicondyle of the femur) were also excluded.

A retrospective chart review was performed to collect data on patient age, sex, duration of symptoms before presentation, and type of symptoms (paresthesias, palpable swelling, tenderness, motor and/or sensory symptoms); in cases of weakness, Medical Research Council (MRC) grades were used to grade strength of the tibialis anterior (TA), extensor hallucis longus (EHL), and peroneus longus (PL) muscles. Sensation on the dorsum of the foot was tested for light touch. Swelling that was palpable during examination was noted.

MRI Analysis

For MRI analysis, the diameter of the lesion was measured on axial postcontrast gadolinium-enhanced T1-weighted images and the length on coronal or sagittal images. All measurements were performed by the first author. Subdivision for the levels proximal to, at, or distal to the FH was determined using sagittal MR images. Lesions proximal to the FH were located between the upper border of the posterior part of the lateral epicondyle of the femur extending to the apex of the FH. Lesions at the FH extended from the apex of the FH to the fibular neck, before the CPN enters the fibular tunnel. Lesions distal to the FH extended from the base of the FH to the bottom of

the fibular neck, the site of the fibular tunnel. Examples are provided in Fig. 2.

Surgery and Outcome

Surgical reports were analyzed for specific notes during the procedure. All procedures were performed using the technique described above (i.e., removal from the pseudocapsule, while leaving the true capsule intact). Examples are provided in Figs. 3 and 4. Postoperative complications were recorded, specifically for increased neurological deficit measured for the MRC grades of ankle dorsiflexion, eversion, and toe and big toe extension. Recovery of motor and sensory deficits, if present preoperatively, was noted, as was decrease or resolution of pain symptoms.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 29. Baseline characteristics between groups of sporadic schwannomas surgically treated at the Haaglanden Medical Center and Mayo Clinic were compared for categorical values using a chi-square test and for linear values using an independent t-test. For comparison of values for the different locations (proximal, at, and distal to the FH), 1-way ANOVA was used with a post hoc Bonferroni test. For the chi-square test, asymptotic significance (2-sided) was noted. For the independent-samples t-test, if there was no significant difference for Levene's test for equality of variances, the 2-sided p values were noted. The paired-samples t-test was used to investigate potential correlation between the duration of symptoms and diameter and length of the tumor. For comparison of tumor size between sporadic schwannomas and schwannomatosis, the t-test was used; $p < 0.05$ was considered statistically significant.

Systematic Review of the Literature

One author (T.F.H.V.) performed a systematic literature search using the PubMed and Embase databases on January 28, 2025, according to the PRISMA guidelines (see Supplemental Appendix 2 for the search strategy).[9] Articles written in the English, French, and Dutch languages were selected and were read by one author (G.C.W.d.R.). Case reports and case series were included if the schwannoma was located in the CPN around the knee and if measurements on the size of the schwannoma were provided, as well as intraoperative findings and outcome.

Results

Sporadic CPN Schwannomas

Twenty-two cases of sporadic schwannomas were found in the database from the Mayo Clinic and 14 cases from the database of the Haaglanden Medical Center. Of these 36 cases, there were 20 cases proximal to the FH, 8 cases at the FH, and 8 cases distal to the FH, of which 1 case involved the articular trunk. The diagnosis was made using tissue obtained after resection. Except for 1 revision case, biopsy was not performed before the surgery. Apart from this revision case, another patient had undergone surgery elsewhere, but the epineurium of the nerve had not been opened and therefore this case was counted as a primary case. Baseline characteristics for the 36 sporadic cases at presentation were not significantly different between the groups who underwent surgery at the 2 institutions (Supplemental Appendix 1). Grouped analysis was therefore performed for all 36 lesions. Results were compared for CPN schwannomas proximal to, at, and distal to the FH. In patients with CPN schwannomas proximal to the FH, the lesion was often first noticed as a palpable swelling on touch or radiating pain on pressure, for example, while sitting on a chair or during movements of the knee (Table 1). For patients with CPN schwannomas distal to the FH, inside the fibular tunnel, symptoms most frequently started with radiating pain without touch. Most of these patients had not noted a palpable swelling before the schwannoma was discovered on MRI. Preoperative deficits were present in 3 cases. In one case, a 63-year-old man presented with paralysis of the EHL muscle after a skiing accident. A CPN schwannoma distal to the FH was detected during analysis of the knee. His weakness completely improved to MRC grade 5 6 months postoperatively. In another case, an 83-year-old man presented with a relatively large CPN schwannoma (4.1 cm in diameter,

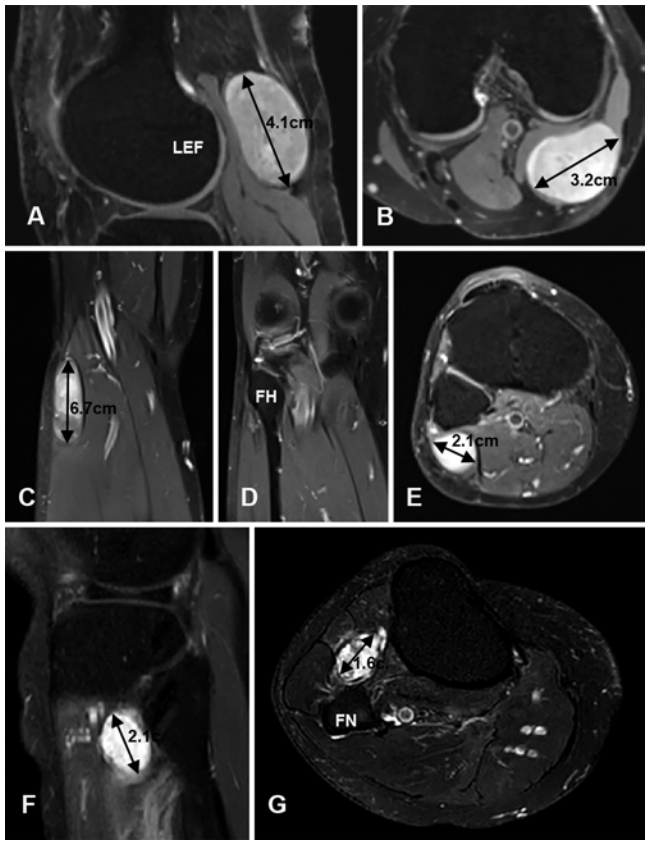

FIG. 2. T1-weighted Gd-enhanced MR images of CPN schwannomas at the three levels investigated in our surgical series. Sagittal (**A**) and axial (**B**) images of a case of a large CPN schwannoma proximal to the FH, at the level of the lateral epicondyle of the femur. Coronal (**C and D**) and axial (**E**) images obtained in a case of a large CPN schwannoma at the FH. Sagittal (**F**) and axial (**G**) images of a relatively smaller CPN schwannoma in the articular branch at the level of the fibular neck.

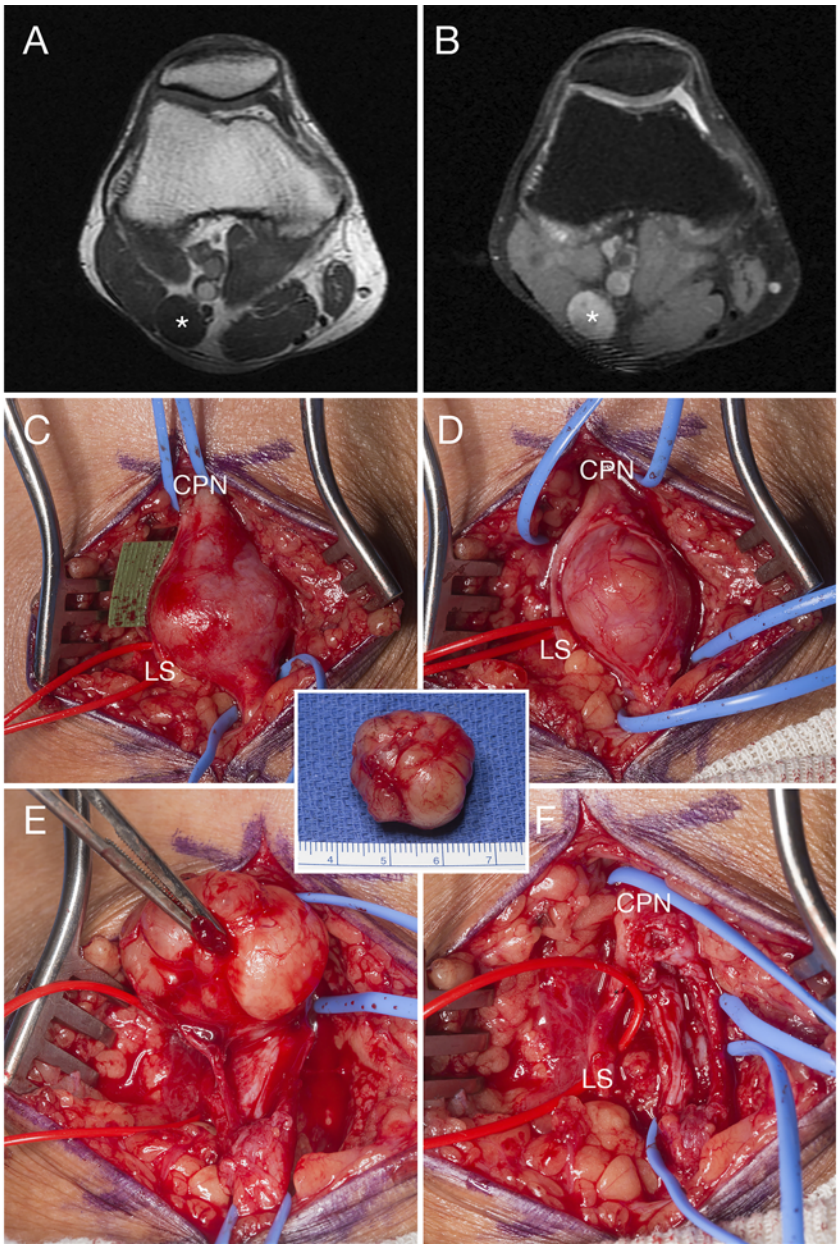

FIG. 3. Example of a CPN schwannoma proximal to the FH at the level of the lateral epicondyle of the femur. **A and B:** Axial T1-weighted (A) and proton density with fat saturation (B) MR images showing the schwannoma (*asterisk*). **C–F:** Intraoperative images showing the lesion in the CPN, next to the lateral sural (LS) nerve (C and D), tumor resection (E and **inset**), and the preservation of the CPN postresection (F).

4.6 cm in length) proximal to the FH. The patient's motor deficit (dorsiflexion MRC grade 4) did not improve after resection. In the final case, a 71-year-old man presented with a CPN schwannoma proximal to the FH. The patient had undergone surgery elsewhere and already presented with deficit (MRC grades 3+ in the TA, 3 in the EHL, and 4– in the PL) as a result of the first attempt at resection. A new postoperative deficit occurred in 3 patients. Two patients experienced temporary weakness that completely resolved within several months (one case with weakness on eversion [MRC grade 4+] and one on dorsiflexion [MRC grade 4]). In both cases weakness resolved within several months. The third case was the revision case, described above, that presented with weakness that deteriorated after surgery (MRC grades 1+ in the TA, 2 in the EHL, and 4– in the PL). In the operative note of that case, dense scarring was noted as well as a small and a large fascicle entering and exciting the tumor that could not be separated. For the primary cases, 6% (2/35) had postoperative motor deficits. Preoperative paresthesias, present in 22 patients, completely resolved, except in 3 cases (14%). Preoperative pain medication was used by 4 patients. Postoperative numbness occurred in 5 patients (14%), but this slowly recovered to normal in all cases.

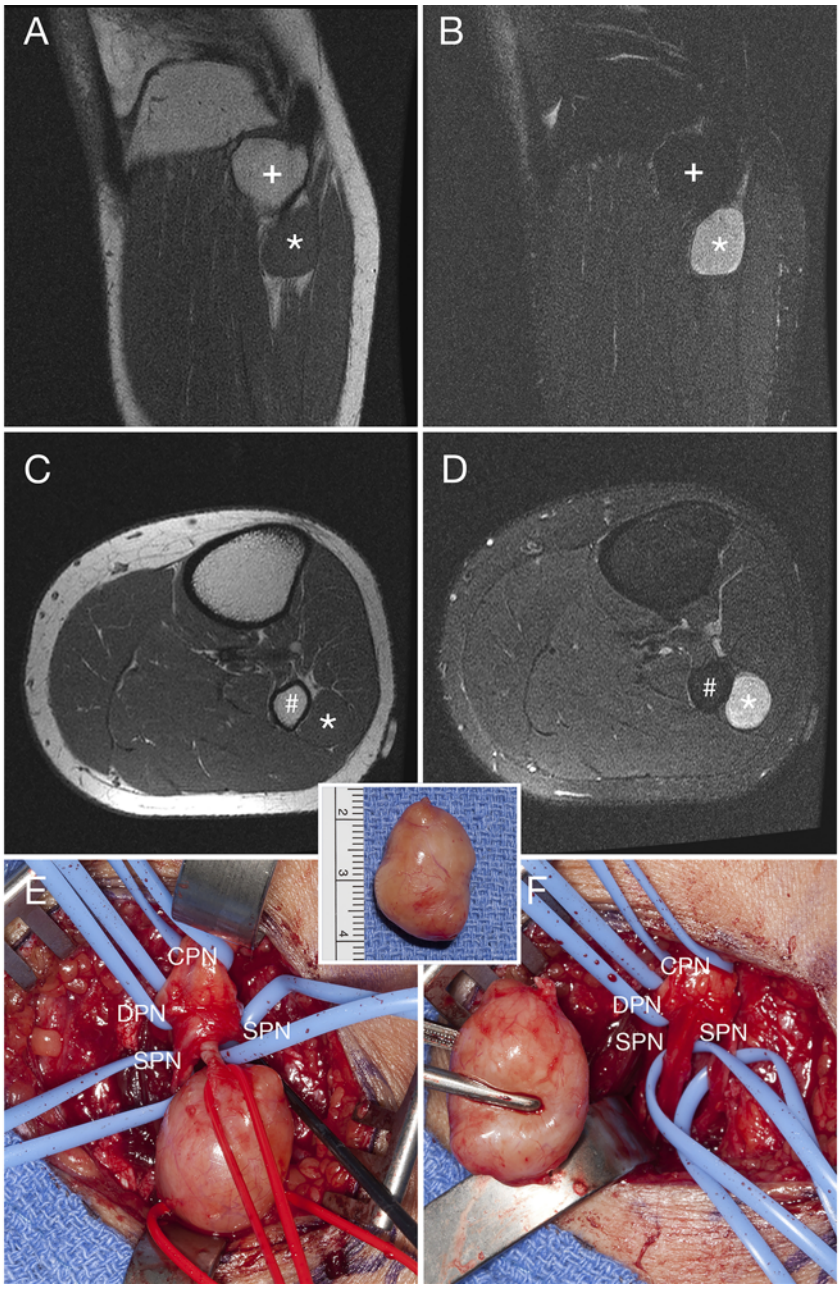

FIG. 4. Example of a CPN schwannoma distal to the FH, at the fibular neck. **A–D:** Preoperative T1-weighted and T2-weighted coronal (A and B) and axial (C and D) MR images. The *asterisks* indicate the location of the tumor; the *plus signs*, the FH; and the *pound signs*, the fibular neck. **E and F:** Intraoperative images showing the enucleation from the superficial peroneal nerve branch (SPN), just distal to the division of the CPN into the superficial nerve and the deep peroneal nerve (DPN) branches.

Comparisons of the different locations around the knee (proximal to, at, and distal to the FH) showed no statistically significant differences. The size of the schwannomas at presentation (both for diameter and length) tended to be smaller for those distal to the FH (1.3 cm and 1.6 cm, respectively) than for those proximal to the FH (2.0 cm and 2.3 cm, respectively) and at the FH (2.2 cm and 2.1 cm, respectively) (Table 1), but these differences were not significant ($p = 0.304$ and $p = 0.252$, respectively). The duration of symptoms tended to be longer for the schwannomas located distal to the FH (42 months) compared with those at the FH (33 months) and proximal to the FH (21 months), but this difference was also not significant ($p = 0.177$). Statistical analysis on size and location for the chance of pre- or postoperative deficits could not be performed due to the small numbers. However, both cases of temporary weakness occurred in the resection of CPN schwannomas located proximal to the FH, and the patient who presented with weakness that did not recover (mentioned above) had the largest schwannoma (4.1 cm) in this series.

TABLE 1. Mean data on CPN schwannomas for sporadic cases (36 patients) and schwannomatosis (12 cases in 8 patients) surgically treated around the knee

	Symptoms					Size on MRI	
	Swelling (%)	Pain on Touch (%)	Pain w/o Touch (%)	Motor Weakness (%)	Duration, mos	Diameter, cm	Length, cm
CPN schwannomas							
Sporadic, n = 36	22 (65)	24 (71)	8 (24)	3 (8.8)	28 (2–120)	1.9 (0.55–6.7)	2.1 (0.54–4.6)
Schwannomatosis, n = 12	7 (88)	1 (12)	7 (88)	1 (12)	20 (1–72)*	1.7 (0.89–3.5)*	2.2 (0.79–3.7)*
Sporadic location around knee							
Proximal to FH, n = 20	20 (100)	19 (95)	2 (10)	2 (10)	21 (2–108)	2.0 (0.55–4.1)	2.3 (0.68–4.6)
At FH, n = 8	2 (25)	2 (25)	2 (25)	0 (0)	33 (12–60)	2.2 (0.71–6.7)	2.1 (1.0–3.6)
Distal to FH, n = 8	0 (0)	1 (14)	6 (71)	1 (14)	42 (10–120)	1.3 (1.1–1.7)	1.6 (0.54–2.7)

Values are presented as the number of patients (%) or mean (range) unless specified otherwise. The mean sizes for the entire cohort (including schwannomatosis cases) for different locations were 2.0 × 2.2 cm proximal, 2.2 × 2.3 cm at, and 1.4 × 1.8 cm distal to the FH (p = 0.117 and p = 0.445, respectively, diameter and length). The duration of symptoms was also not significantly different for the total cohort (21 months for schwannomas proximal to the FH, 27 months for at the FH, and 35 months for distal to the FH [p = 0.344]).

* Not significantly different between sporadic schwannomas and schwannomatosis (p = 0.321 for duration of symptoms, p = 0.569 for diameter, and p = 0.508 for length).

CPN Schwannomas in Cases of Schwannomatosis

Twelve CPN schwannomas were resected in 8 patients with schwannomatosis. Two cases were related to NF2. The mean diameter and length of the tumors were not significantly different from those for sporadic schwannomas (Table 1). Most patients (88%) with schwannomatosis presented with pain (3 were on pain medication). In 3 cases, a preoperative biopsy had been performed. There were 3 cases of segmental schwannomatosis: in one case, 2 CPN schwannomas were removed during the same procedure (Fig. 5), and in another case, 3 CPN schwannomas were removed at 1- and 7-year intervals. There were 2 plexiform schwannomas: in one case with 2 CPN schwannomas, one lesion was internally debulked, and in the other case, the patient developed complete paralysis of dorsiflexion and eversion postoperatively that recovered partly to MRC grade 2 for dorsiflexion and MRC grade 3 for eversion. Pain symptoms improved in all patients postoperatively but sometimes recurred due to growth of a previously asymptomatic lesion.

Systematic Review of the Literature

A total of 421 articles were found using the search criteria presented in Supplemental Appendix 2. After carefully reading the abstract, 42 articles were selected for full reading (Fig. 6). Sixteen articles were excluded because the schwannoma was located proximally or distally to the level of the knee, 11 had insufficient data, and 1 was written in Korean. In addition, after reading the 14 remaining articles, 3 new references to case reports of CPN schwannomas were identified. Full-text articles were retrieved and included. This led to a total of 17 articles published between 1998 and 2024 (Table 2) with details for 21 cases of CPN schwannomas. There were 4 giant schwannomas (> 5 cm);[10–14] 3 of these caused weakness after resection. In 7 patients a foot drop or weakness of dorsiflexion was noted after surgery. Preoperative motor deficit was reported in 7 cases.[15] In 3 cases this worsened after the surgery,[16–18] in 3 cases it recovered[15] (in 1 case neurological outcome was not reported[19]). Recovery of hypesthesia and dysesthesia was reported in 3 cases.[20–22]

Discussion

This study shows that schwannomas in the CPN near the FH, similar to other nerves and other sites, can be resected safely. Motor deficit after resection of CPN schwannomas in our series was observed in only 3 cases: 2 of 35 primary cases and 1 case in which surgery was previously performed. The deficit in these primary cases was relatively mild (MRC grade 4) and completely recovered within several months. This complication rate (6%) is comparable to the overall rate for motor deficit after surgery for peripheral nerve schwannomas, including other locations (e.g., in the studies by Guha et al. [10.3%],[23] Levi et al. [8%],[24] and Raj et al. [12.7%][25]), which is interesting, because the CPN generally is vulnerable to injury and is associated with poor outcomes after nerve reconstruction. To the best of our knowledge, this is the first study that has reported the risk for motor deficits after resection of CPN schwannomas. In our systematic literature review, only case reports[8,10–14,16–22,26–28] and one small case series[15] were found, in which details for schwannoma size, deficit, and outcome were reported. In addition, there was one series by Kim et al.[3] on surgical outcomes for schwannomas arising from major peripheral nerves in the lower limb. This series was excluded from the review (because details on schwannoma size were not provided) but is worth mentioning, because 2 complicated cases of CPN schwannomas were described in detail. One case concerned a 41-year-old female with postoperative grade 3 motor weakness and neuropathic pain, and one case a 27-year-old female with sensory deficit. As potential explanations for these deficits, the authors of the first case mentioned that nerve fascicles were found intraoperatively to enter the tumor mass, and for the second case, 2 nerve fascicles were damaged intraoperatively and were repaired. Moreover, in the case report by Levin et al.,[17] a fascicle entering the tumor was mentioned as the reason for developing a foot drop. These cases stress the

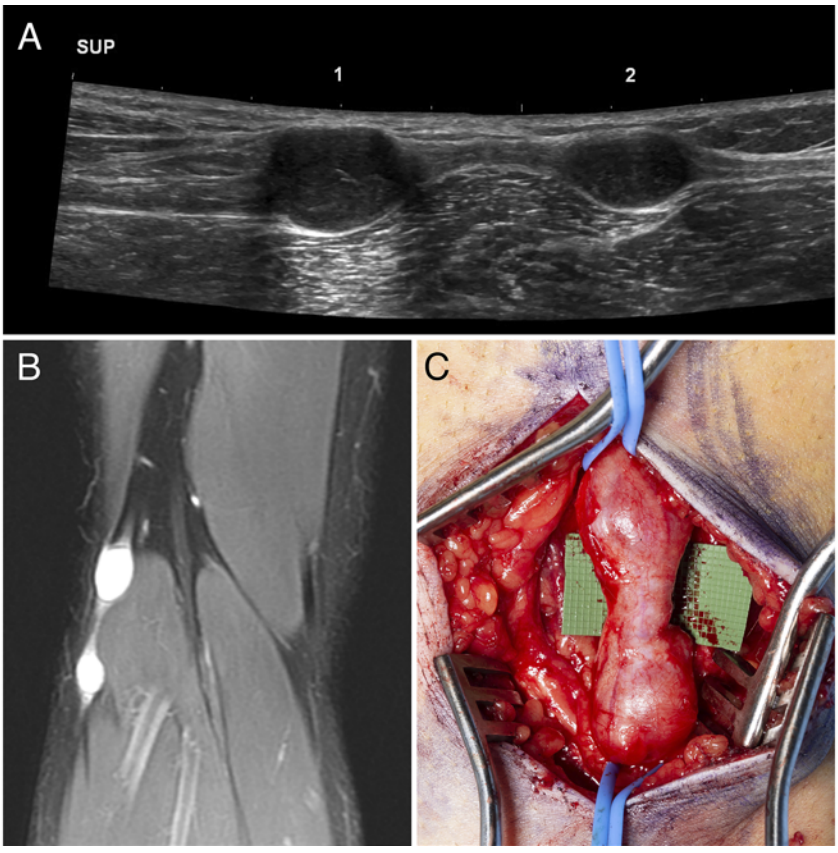

FIG. 5. Example of a case of schwannomatosis with 2 schwannomas in the CPN. **A:** Preoperative ultrasound images showing 2 hypoechoic lesions in the course of the CPN. **B:** Coronal T1-weighted Gd-enhanced MR image demonstrating the same lesions in the CPN. **C:** Intraoperative photograph of the 2 lesions in the CPN that were resected during the same surgery.

importance for using mapping and intraoperative bipolar stimulation and the importance of adhering to the correct resection procedure,[5] which preferably is performed using magnification (loupe or a microscope) to better appreciate the right layer that has to be found ("go for the gold"[1]). If bipolar stimulation of the isolated fascicle proximal to the schwannoma still results in muscle contraction (dorsiflexion or eversion), most likely the right plane has not yet been found and the fascicles should be carefully dissected, with specific attention to the relation with the tumor at the poles.[5] Finally, it is important to note that the procedure described above should also be performed in case of involvement of the articular trunk (Fig. 2F and G), because in some anatomical variations a branch to the TA muscle can come from this branch and in toto resection can lead to permanent deficit.[29]

Our article describes the importance of applying the correct technique during the first surgical procedure. In our series there was 1 revision case that presented with motor deficit as a consequence of the first surgery, which deteriorated after the second surgery. In the series reported by Kim and Kline,[30] of 7 CPN schwannomas, there was 1 case that first had been treated elsewhere, in which the nerve during the second surgery had to be repaired with a graft.

Our systematic literature review showed that in cases in which a schwannoma before surgery was not suspected and resection was probably not performed using the correct technique, that surgery resulted in neurological deficit.[8,10] Preoperative biopsy of schwannomas preferably should not be performed if clinicoradiological features are consistent with a benign lesion, because it can make resection more difficult and has been shown to increase the chance for postoperative neurological deficits.[24,31] In our series, preoperative biopsy had not been performed in any of the sporadic cases but was done in 3 of 8 cases of schwannomatosis. Finally, other pathologies, such as an intraneural ganglion cyst[32] can also occur, and other treatments might have been performed before the surgery (such as ozone therapy[16]).

In our series a preoperative motor deficit was present in 2 cases. In one case, EHL muscle weakness (MRC grade 1) completely recovered half a year after the surgery, and in the other, weakness of ankle dorsiflexion did not improve after surgery. In our systematic literature review, there was one case series by Andreani et al. that included 5 CPN schwannomas,[15] in which 3 cases with preoperative deficits were reported: 2 cases with weakness of the anterior and/or lateral compartment of MRC grade 4 that postoperatively improved to MRC grade 5, and 1 case of MRC grade 3 that postoperatively improved to MRC grade 4. In the same study, the functional status of patients was evalu-

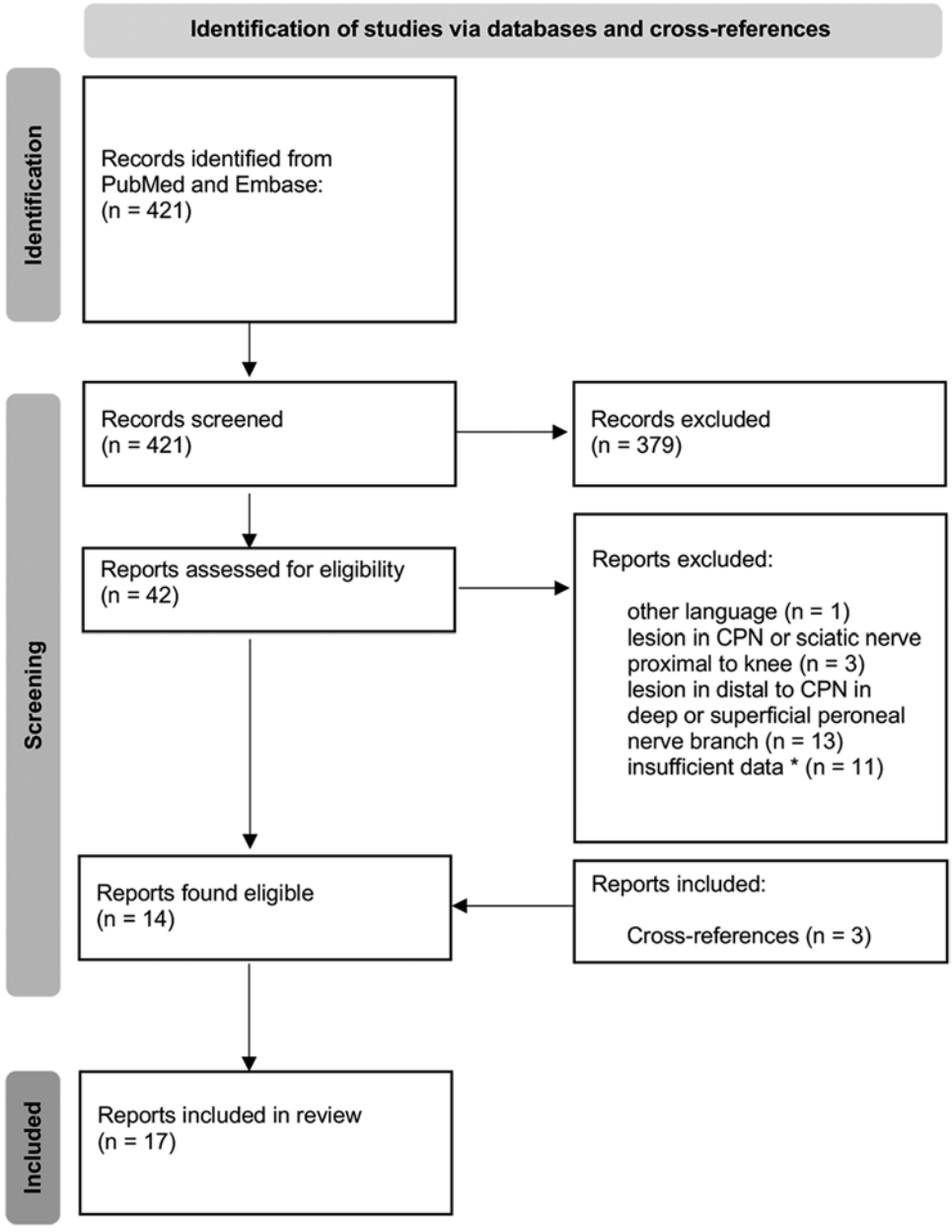

FIG. 6. PRISMA flow diagram for the systematic review on cases and series reporting resection of CPN schwannomas. Reports with lesions in the CPN or sciatic nerve proximal to the knee and lesions distal to the CPN in deep or superficial peroneal nerve branches were excluded. Insufficient data included reports with no MRI/ultrasound studies with schwannoma measurements, no surgical details on postoperative outcomes, and in one case, only video. Data added to the PRISMA template (from Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71) under the terms of the Creative Commons Attribution (CC BY 4.0) License (https://creativecommons.org/licenses/by/4.0/).

ated using the Lower Extremity Functional Scale and the Musculoskeletal Tumor Society scores. Both scores for 9 cases of peroneal nerve schwannomas (including 1 in the deep and 3 in the superficial peroneal branches) significantly increased postoperatively. Tumor size was positively correlated with this increase. For the 5 CPN schwannomas, 4 preoperative moderate sensory deficits improved to normal, and 1 severe sensory deficit improved to moderate. Pain and paresthesias recovered in most patients (86%). Sensory deficit after surgery occurred in 5 patients (14%) but was temporary and in all cases recovered to normal. In our systematic review, there were 3 cases in which hypesthesias/dysesthesias improved after the surgery.

Tumor size has been suggested in several studies to correlate with the chance of postoperative deficit.[3,33] In our study, no relation between tumor size and development of deficit was found, but there were only a few patients with postoperative deficits and most tumors were relatively

TABLE 2. Results from the systematic literature review on previously reported cases of surgically treated CPN schwannoma around the knee

Authors & Year	No. of Cases	Age (yrs), Sex	Schwannoma		Preop Symptoms	Preop Neurological Exam	Postop Deficit/ Improvement
			Location*	Size, cm			
Maleux et al., 1997[13]	1	16, F	At FH	25 in length	Discovered after trauma	Not specified	No deficit
Houshian & Freund, 1999[12]	1	47, F	Prox to FH	12 × 8 × 5	8 yrs, pain	Not specified	Foot drop
de Jonge et al., 2005[8]	1	30, F	Prox to FH	4.0	5 yrs, painful swelling	Not specified	Paralysis TA, PL, & EHL muscles, sensory deficit
Rafai et al., 2006[19]	1	70, F	Prox to FH	2.0 × 2.5	4 mos, paresthesias	Foot drop, atrophic muscles, hypesthesia dorsum foot	Not specified
Levin et al., 2017[17]	1	50, M	Prox to FH	3.0 × 2.0	6 mos, pain w/ flexion knee	Mild weakness	Foot drop & numbness anterolat part of leg
Öz et al., 2017[21]	1	39, F	At FH	1.1	3 mos, pain	Numbness	Pain relief
van Zantvoort et al., 2017[20]	1	41, F	At FH	1.3 × 0.7	8 yrs, pain on touch	Hypesthesia dorsum foot	Pain relief
Milenkovic & Mitkovic, 2018[28]	1	41, M	Prox to FH	3.0 × 2.5	5 mos, pain on movement	Normal	No deficit
Georgiev et al., 2021[14]	1	81, F	At FH	7.0	20 yrs, swelling	No deficit	No deficit
Panchariya et al., 2020[27]	1	12, M	Prox to FH	2.9 × 1.8 × 3.0	5 yrs, swelling	Normal	No deficit
Vetrano et al., 2020[16]	1	23, M	Prox to FH	1.2 × 1.3	1 yr, painful swelling	Slight dorsiflexion deficit	Worsening dorsiflexion recovered at 12-mo FU
Abebe & Weldemicheal, 2023[22]	1	45, F	Dist to FH	4.5 × 2.5 × 2.3	4 yrs, pain	Hypesthesia dorsum foot	Improved sensation
Andreani et al., 2022[15]	5	39, 72, 54, 48, & 44	CPN†	2.0, 3.0, 4.2, 2.5, & 3.9	1 case of swelling	4 cases sensory deficit, 2 cases MRC 4, 1 case MRC 3	MRC 4 cases → MRC 5; MRC 3 cases → MRC 4
Harahap & Harahap, 2024[11]	1	37, F	Prox to FH	5 × 4.5 × 4	4 yrs, swelling w/ pain on touch	Hypesthesia dorsum foot	Foot drop
Ramachandran & Shankar, 2024[26]	1	50, M	Prox to FH	1 × 1.5	Pain w/ movement & touch	No deficit	No deficit
Tamulionis et al., 2024[10]	1	32, M	Prox to FH	9.6 × 7.8 × 6.5	6 mos, swelling w/ pain	No deficit	Impaired dorsiflexion
Yalcinkaya et al., 2024[18]	1	47, M	Prox to FH	3.5 × 1.0	1 yr, swelling	Dorsiflexion & eversion MRC 3	Worsening to MRC 1

Dist = distal; FU = follow-up; prox = proximal.

* In relation to the fibular head.

† The exact location in relation to the FH was not specified.

small. In the study by Andreani et al. there was a significant positive correlation between duration of symptoms and tumor size at the time of the procedure.[15] Tumor size in that study was also negatively correlated with the preoperative MRC scores. One of the goals of our study was to compare the size and duration of symptoms for different zones around the knee. Although schwannomas at the fibular tunnel tended to be smaller compared with more proximally located tumors, this difference was not significant. At the same time, the duration of symptoms for the distal group tended to be longer. This can be explained by the finding that more proximally located schwannomas were frequently detected by the patient as swelling, while in the distal group the first symptoms often consisted of pain and paresthesias. We expected that smaller schwannomas at the fibular tunnel would produce symptoms, because of the compression inside the tunnel, but the finding that this difference did not reach statistical significance might thus have been caused by differences in presentation. It is possible that CPN schwannomas distal to the FH present relatively later, because the lesion is covered by the peroneal muscles and therefore was often not detected by the patient, while more proximal CPN schwannomas often presented with swelling and were detected at an earlier moment. In addition, CPN schwannomas at the level of the lateral epicondyle of the femur frequently presented with local pain or paresthesias while sitting (due to pressure at the site of the lesion) or with movements of the knee. This can be explained by the relative superficial course of the CPN at this level.

Expectant management with wait-and-scan is often performed in patients with schwannomas. Although based on the results of our series it is difficult to suggest that all CPN schwannomas should be surgically treated, we have

a preference for surgical treatment, because 1) resection of larger CPN schwannomas is more likely to result in neurological deficit, and 2) in the case of preoperative weakness, it is uncertain whether the deficit will recover. In our systematic literature review, relatively large CPN schwannomas were also found (> 5 cm, considered giant or gigantic).[10,12–14] Neurological deficits more frequently occurred in these cases than in our surgical series. Although the results cannot be directly compared, this does suggest that patients with larger tumors are at higher risk for developing postoperative deficits.[3,33] These findings might help in surgical decision-making, because in sporadic schwannomas symptoms frequently occur only on touch and patients might be reluctant to undergo surgery. This is in contrast to patients with schwannomatosis, who frequently present with pain symptoms,[34] as was also found in our study (Table 1). In schwannomatosis, other factors can complicate surgical decision-making, such as which lesion(s) to resect and when to perform intracapsular debulking instead of resection. A subgroup of tumors associated with schwannomatosis are more complex, including multifascicular or plexiform lesions, which might be associated with a higher complication rate when occurring in major nerves.[35] Of course, other factors besides symptoms and tumor size need to be considered, such as the age of the patient and the growth rate of the tumor.

Limitations

Our study has several limitations. First, the size of the CPN schwannomas in our series was relatively small, especially when compared with the giant cases reported in the literature. It is important to realize that this might have influenced the occurrence of postoperative complications. It is possible that patients in the US and Europe present earlier than in other parts of the world.

Second, the subdivision that was made in this study into three different groups based on location of the schwannoma in relation to the FH is subject to anatomical variations. We based our subdivision on a cadaveric study by Ryan et al. that showed that the bottom of the fibular tunnel is consistently formed by the fibular neck and starts just distal to the FH.[36] Although the anatomy in that study with 30 lower limbs (15 cadavers) was quite consistent, there may be variations in the start of the fibular tunnel in relation to the FH. This might have affected our results. Third, we did not analyze recovery of sensation objectively with, for example, Semmes-Weinstein filaments. To the best of our knowledge, this has not been systematically performed before in other surgical series of schwannomas but would provide better insight into the effect of surgery on recovery or worsening of sensation. Also, pain scores were not systematically obtained in this surgical series. Ideally, these would be obtained before and at different time points after the surgery using visual analog or numeric rating scores. MRI scans were also not obtained systematically in all patients postoperatively, but as recently shown, the value of MRI during follow-up after resection is limited.[2] Finally, some of the patients in this series with sporadic tumors might, in fact, have or develop other undiagnosed schwannomas and might meet criteria as having schwannomatosis.

Conclusions

The results of this case series show that CPN schwannomas can be safely removed with a small chance of developing temporary neurological deficits. A systematic review of the literature further suggested that the chance for permanent deficits is higher in larger CPN schwannomas. Based on this combination of findings, we believe that resection of CPN schwannomas can best be performed after presentation, even when the schwannoma is relatively small. Biopsy should only be considered with larger lesions or those tumors with unusual clinicoradiological features. Finally, the first surgery should be performed using the right technique with bipolar stimulation and the use of magnification, because the chance for neurological deficits in revision cases is much higher.

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Disclosures

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Author Contributions

Conception and design: Spinner, de Ruiter. Acquisition of data: Spinner, Hayford, de Ruiter. Analysis and interpretation of data: Spinner, de Ruiter. Drafting the article: Spinner, de Ruiter. Critically revising the article: Spinner, de Ruiter. Reviewed submitted version of manuscript: Spinner, de Ruiter. Approved the final version of the manuscript on behalf of all authors: Spinner. Study supervision: Spinner. Search strategy: Vissers.

Supplemental Information

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Correspondence

Robert J. Spinner: Mayo Clinic, Rochester, MN. spinner.robert@mayo.edu.