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Clinical outcome after decompression of intraneural peroneal ganglion cyst and its morphologic correlation to postoperative nerve ultrasound

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OBJECTIVE Intraneural ganglion cysts are rare and benign mucinous lesions that affect peripheral nerves, most frequently the common peroneal nerve (CPN). The precise pathophysiological mechanisms of intraneural ganglion cyst development remain unclear. A well-established theory suggests the spread of mucinous fluid along the articular branch of the peroneal nerve as the underlying mechanism. Clinical outcome following decompression of intraneural ganglion cysts has been demonstrated to be excellent. The aim of this study was to evaluate the correlation between clinical outcome and ultrasound-detected morphological nerve features following decompression of intraneural ganglion cysts of the CPN.

METHODS Data were retrospectively analyzed from 20 patients who underwent common peroneal nerve ganglion cyst decompression surgery at the Universität Ulm/Günzburg Neurosurgery Department between October 2003 and October 2017. Postoperative clinical outcome was evaluated by assessment of the muscular strength of the anterior tibial muscle, the extensor hallucis longus muscle, and the peroneus muscle according to the Medical Research Council grading system. Hypesthesia was measured by sensation testing. In all patients, postoperative morphological assessment of the peroneal nerve was conducted between October 2016 and October 2017 using the iU22 Philips Medical ultrasound system at the last routine follow-up appointment. Finally, the correlations between morphological changes in nerve ultrasound and postoperative clinical outcomes were evaluated.

RESULTS During the postoperative ultrasound scan an intraneural hypoechogenic ring structure located at the medial side of the peroneal nerve was detected in 15 (75%) of 20 patients, 14 of whom demonstrated an improvement in motor function. A regular intraneural fasicular structure was identified in 3 patients (15%), who also reported recovery. In 1 patient, a recurrent cyst was detected, and 1 patient showed intraneural fibrosis for which recovery did not occur in the year following the procedure. Two patients (10%) developed neuropathic pain that could not be explained by nerve ultrasound findings.

CONCLUSIONS The results of this study demonstrate significant recovery from preoperative weakness after decompression of intraneural ganglion cysts of the CPN. A favorable clinical outcome was highly correlated with an intraneural hypoechogenic ring-shaped structure on the medial side of the CPN identified during a follow-up postoperative ultrasound scan. These study results indicate the potential benefit of ultrasound scanning as a prognostic tool following decompression procedures for intraneural ganglion cysts of the CPN.

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KEYWORDS intraneural ganglion cyst; peroneal nerve; nerve ultrasound; peripheral nerve

ABBREVIATIONS ATM = anterior tibial muscle; CPN = common peroneal nerve; EHLM = extensor hallucis longus muscle; MRC = Medical Research Council; PM = peroneus muscle.

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Over the last 15 years, pathogenesis of intraneural peroneal ganglion cysts has been intensively studied.[2] The generally accepted "synovial theory" postulates that a capsule defect in the superior tibiofibular joint, caused by previous trauma or degeneration, leads to the intraneural spread of mucinous fluid along the articular branch of the common peroneal nerve (CPN).[13] Biomechanically, pressure results in cyst expansion. Due to topographical distribution of fascicular structures, cysts tend to affect the medial aspect of the CPN first and lead to compression of the fascicles of the deep peroneal nerve, which results more commonly in pronounced weakness of the anterior tibial muscle (ATM) rather than in lesions of the superficial portion of the peroneal nerve.[13] A review of the literature relating to decompression surgery for intraneural ganglion cysts of the peroneal nerve demonstrates that the recovery of clinical symptoms is related to the follow-up period.[16] The rate of recurrent cysts has been demonstrated to be in the region of 11%.[2] The standard surgical treatment procedure, described by Spinner et al., is decompression of the cyst and ligation of the articular branch.[13]

High-resolution ultrasound has been established over years of technical progress as an effective and fast diagnostic tool to evaluate pre- and intraoperative peripheral nerve lesions.[4–6] In the transverse plane in a healthy nerve, a characteristic "honeycomb" fascicular structure can be identified. A ganglion cyst typically features as an anechogenic fluid collection with dorsal through transmission[1] (Fig. 1).

However, the clinical utility of morphological examination of the peroneal nerve after decompression of intraneural ganglion cysts by using nerve ultrasound has not yet been examined. To the best of our knowledge this is the first study to compare clinical outcomes to ultrasound features of intraneural structures of the CPN following decompression of an intraneural ganglion cyst.

Methods

This retrospective, single-center study was approved by the Ethical Review Committee at the University of Ulm, Germany.

A total of 20 patients were examined clinically and by nerve ultrasound retrospectively after decompression of a peroneal ganglion cyst during the period between October 2016 and October 2017. The mean postoperative follow-up time was 20 months (range 2–133 months). This ultrasound scan was conducted during the patient's intended final follow-up appointment.

Motor functions of the anterior tibial muscle (ATM), extensor hallucis longus muscle (EHLM), and peroneus muscle (PM) were tested in all patients pre- and postoperatively by using the Medical Research Council (MRC) grading system, which grades muscle strength from 0 to 5. Preoperative muscle strength was taken from patient records. Additionally, patients' specifications of pain and sensory deficits were recorded at the time of the postoperative ultrasound examination and compared to the preoperative findings.

The surgical technique used was in line with that described by Spinner et al.[12] However, surface resection of the superior tibiofibular joint was not performed. In all cases the tendon of the long PM was incompletely notched and the intraneural ganglion cyst was opened and decompressed. In addition, the articular branch of the common peroneal nerve was ligated and severed to prevent recurrence.

Statistical Analysis

Since muscular strength was measured on an ordinal scale, a nonparametric paired permutation test[7] was used to assess whether muscular strength differed between pre- and postoperative measurements (adjusted for multiple testing using the Bonferroni-Holm method, $n = 20$).

Neurosonography

Postoperative neurosonography was conducted using an iU22 machine in conjunction with a linear array transducer (L15-7io) (Philips Medical Systems) in an axial view. The anatomy of relevance included the intraneural structures from the CPN trifurcation at the level of the fibular neck to the junction with the tibial part in the popliteal fossa. Representative pictures and video sequences were documented. The medial side was defined as that facing the articular branch of the CPN, and the lateral side was thus defined as that facing the superficial branch. Results were classified into regular intraneural structures, cyst recurrence, intraneural fibrosis, and newly observed intraneural hypoechogenic ring structures. The relation of improvements in pain and motor function to these ultrasound findings was evaluated.

Results

In the cohort of patients identified as having intraneural ganglion cysts of the peroneal nerve, 90% presented with paresis of the ATM and/or EHLM. Seventeen patients (85%) reported pain at the level of the fibular neck as an initial clinical symptom that persisted until surgery. For 2 patients (10%), pain was the presenting symptom without noted paresis. Three patients (15%) were operated on twice, one of whom required a third operation due to cyst recurrence. The mean age of patients was 55 years (range 32–78 years). The mean duration of symptoms prior to surgery was 12.2 weeks (range 2–56 weeks).

Postoperative results showed significant recovery from preoperative weakness in all muscles (p value for ATM, < 0.001; EHLM, 0.001; and PM, < 0.001). The improvement in the function of the ATM postoperatively was from a mean MRC grade of 2 to grade 4 ($p < 0.001$). The mean postoperative duration until follow-up examination was 20 months. Demonstrated improvement in EHLM function according to the MRC grade was from grade 1.5 to grade 3.5 ($p = 0.01$) and for PM function from grade 2.5 to grade 5 ($p < 0.001$).

Fifteen (88%) of 17 patients who had pain as the initial symptom recovered completely from pain after surgery, whereas 2 (11%) of the 17 patients developed neuropathic pain requiring analgesic medication. Twelve (63%) of 18 patients who presented with hypesthesia before surgery reported reduction of the hypesthetic area or complete re-

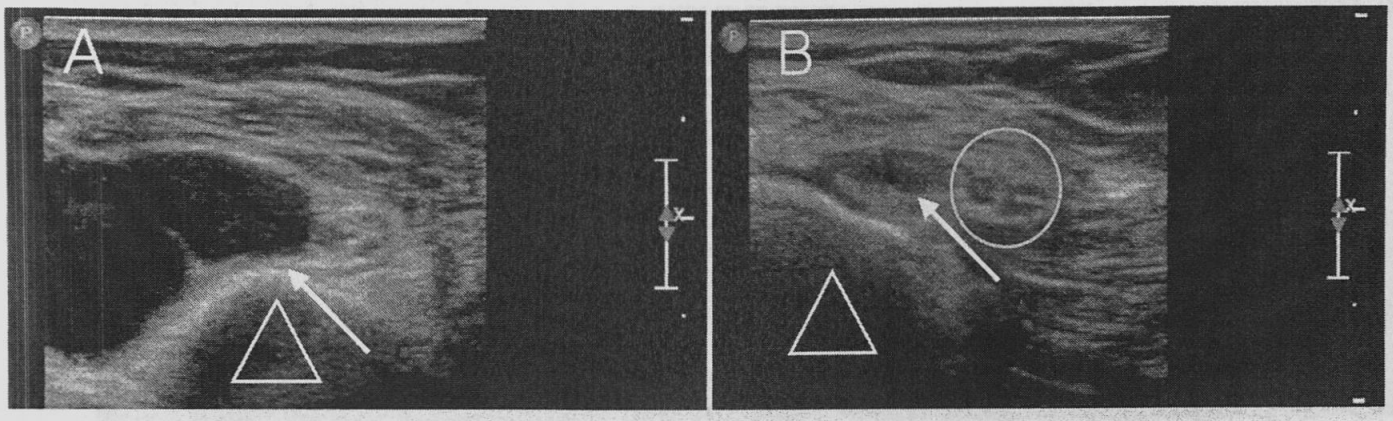

FIG. 1. Intraneural ganglion cyst of the peroneal nerve. **A:** Cyst within the articular branch just rounding the fibular head (*white triangle*) with dorsal through transmission characterizing cyst fluid in the ultrasound image (*white arrow*). **B:** The same nerve just proximal to the fibular head, where the articular branch joins the common peroneal nerve (*white arrow* and *yellow circle*). Figure is available in color online only.

covery. Complete recovery was defined as no limitation in everyday life.

Postoperative Morphology of the Peroneal Nerve in High-Resolution Ultrasound

For data analysis, patients were stratified into two groups. The first group (group 1) consisted of 18 patients who had recovered from impaired motor function after surgery and the second group (group 2) consisted of those who did not. In group 1, 14 (77%) of 18 patients showed an intraneural hypoechogenic ring structure (which differed in shape and size in different patients) at the medial side of the common peroneal nerve (Figs. 2 and 3). Three patients (17%) showed regular intraneural fascicular structures. The findings of 1 patient (6%), whose symptoms had improved nevertheless, demonstrated a recurrent cyst. In group 2 (those patients who did not demonstrate an improvement in motor function), one patient showed distinct intraneural fibrosis of the CPN and the other patient had a hypoechogenic ring structure at the medial side of the CPN with no further changes in fascicular structure (Figs. 4 and 5).

In the 2 patients who developed neuropathic pain along the area of the CPN but who had both recovered from preoperative impaired motor function, one patient was operated on twice because of cyst recurrence and the other patient had a long interval between onset of severe paresis and surgical treatment. In both cases, a neuroma or other specific lesion could not be identified in the postoperative nerve ultrasound examination.

Discussion

A retrospective analysis of patients treated at our department was performed and focused on the correlation of detailed ultrasound-based morphological evaluation with clinical outcomes of patients after decompression of peroneal ganglion cysts.

The structure of an intraneural ganglion cyst consists of a cyst capsule and mucinous fluid. Its extent seems to be the result of a dynamic process. Our morphological findings in postoperative neurosonography demonstrate that an intraneural hypoechogenic ring structure of the common peroneal nerve (Figs. 2 and 3) without compression of surrounding fascicle structures after decompression of intraneural ganglion cysts results in significant clinical

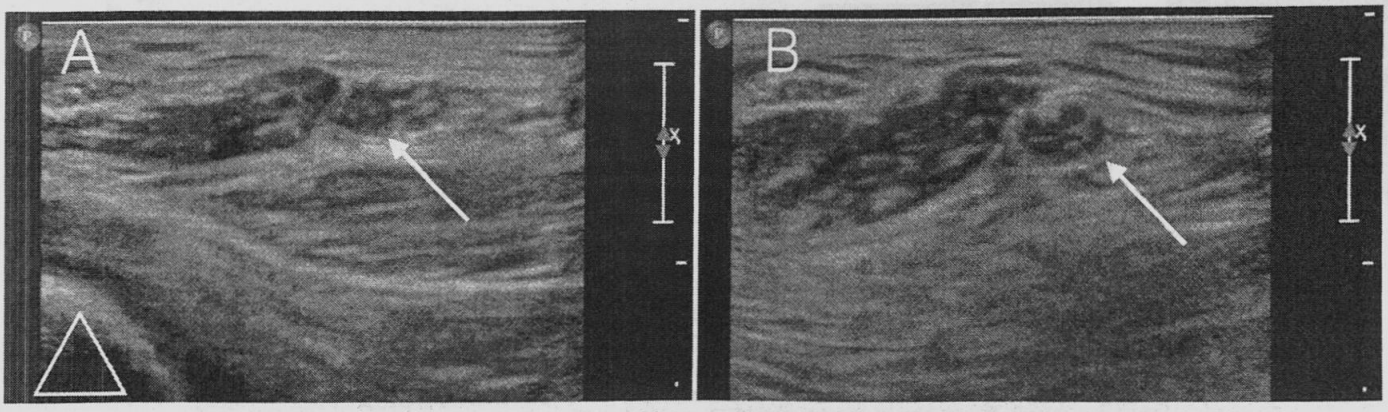

FIG. 2. Patient 6. **A:** Intraneural hypoechogenic ring structure (*white arrow*) on the medial side of the peroneal nerve at the level above the fibular head (*white triangle*). **B:** The same nerve proximal to the fibular head with normal intrafascicular structure 144 months postoperatively (*white arrow*). Figure is available in color online only.

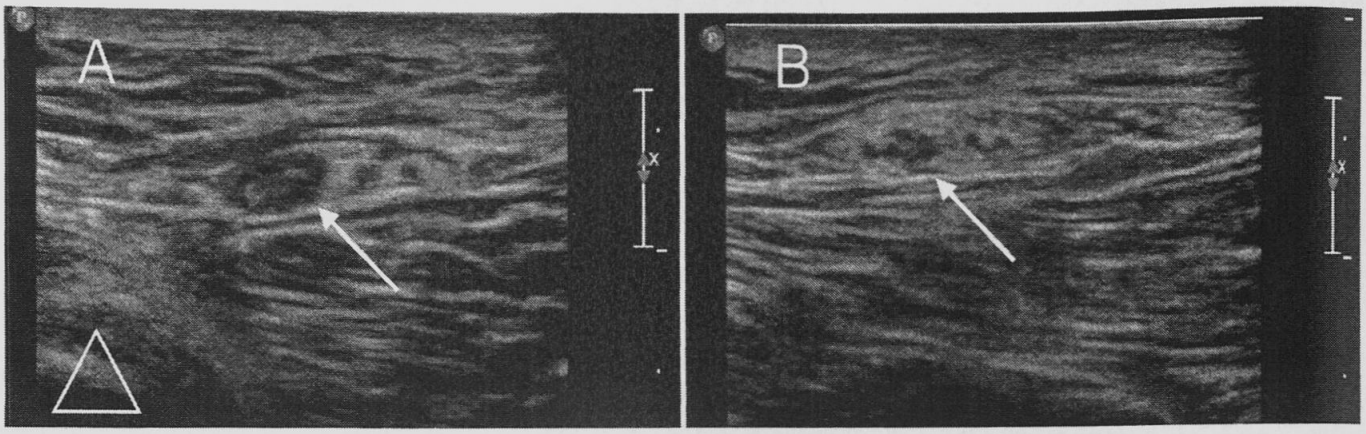

FIG. 3. Patient 7. **A:** Intraneural hypoechogenic ring structure (*white arrow*) on the medial side of the peroneal nerve at the level above the fibular head (*white triangle*). **B:** The same nerve again proximal to the fibular head 10 months postoperatively (*white arrow*). Figure is available in color online only.

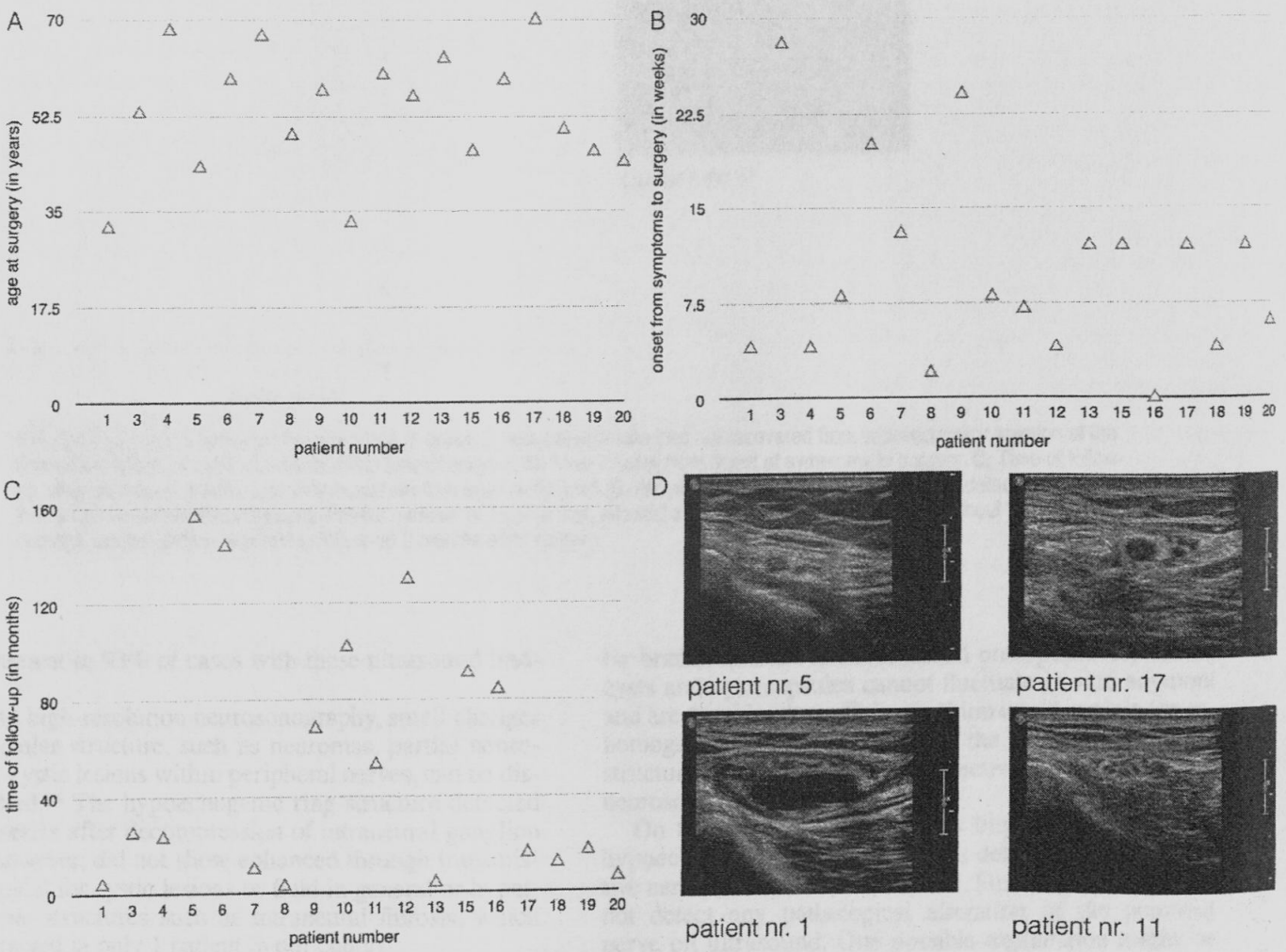

FIG. 4. Demographic baseline characteristics of group 1, with patients who recovered from impaired motor function. **A:** Age of patients at the time of surgery. **B:** Time interval from onset of symptoms to surgery. **C:** Time of follow-up, when neurosonography and clinical examination were performed. **D:** Representative patient ultrasound images. Hypoechogenic ring structure in postoperative neurosonography, which could be detected in 77% of the patient cohort, is shown in representative ultrasound images of patients 5 and 17. Patient 1 presented with a recurrent cyst but showed recovery as well. Patients 10, 11, and 16 showed regular fascicular structure in neurosonography postoperatively at the time of follow-up (shown in representative ultrasound image of patient 11). In patients 3 and 6, who developed neuropathic pain, no other alterations that could be responsible for pain were detected sonographically. Neruosonography showed only the hypoechogenic ring structure. nr. = number.

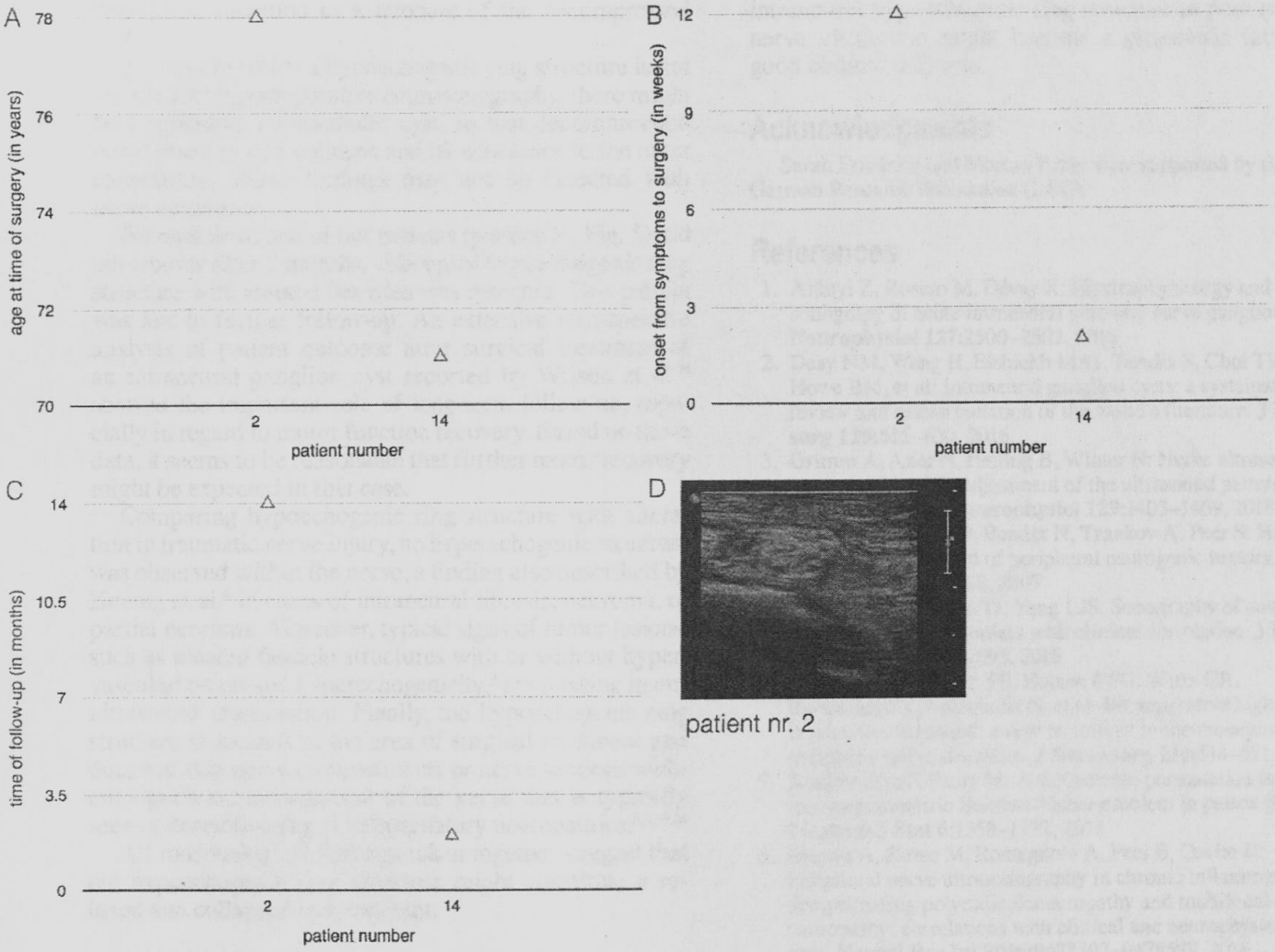

FIG. 5. Demographic baseline characteristics of group 2, with patients who had not recovered from impaired motor function at the time of this report. **A:** Age of patients at the time of surgery. **B:** Time interval from onset of symptoms to surgery. **C:** Time of follow-up, when neurosonography and clinical examination were performed. **D:** An intraneural fibrosis, which could be detected in patient 2, is shown in the neurosonography. Patient number 14, by contrast, showed a hypoechogenic ring structure without further nerve damage, but this patient was lost to follow-up 2 months after surgery.

improvement in 93% of cases with these ultrasound findings.

Using high-resolution neurosonography, small changes in fascicular structure, such as neuromas, partial neuromas, or cystic lesions within peripheral nerves, can be distinguished.[5,6] The hypoechogenic ring structure detected in our series after decompression of intraneural ganglion cysts, however, did not show enhanced through transmission typical for cystic lesions or fluid in general or hyperechogenic structures such as intraneural fibrosis, which was detected in only 1 patient in our cohort.

Furthermore, hypoechogenic structures were located at the medial side of the common peroneal nerve. We interpret these morphological changes as an adherence of the remnant cyst capsule because it is topographically located near its origin, which is adjacent to the articular branch. As a consequence of dynamic cyst formation, as described by Wilson et al.,[15] we propose that remnants of an adherent cyst capsule persist after ligation of the articular branch and are not reabsorbed postoperatively. These cysts and cyst capsules cannot fluctuate in size anymore and are fixed in place. This condition could explain the inhomogeneous longitudinal size of the hypoechogenic ring structure seen in our patients collectively in postoperative neurosonography.

On the other hand, 3 patients improved although no hypoechogenic ring structure was detected in postoperative nerve ultrasound examination. Furthermore, we could not detect any pathological alteration of the peroneal nerve on ultrasound. One possible explanation might be the compartment in which the cyst is localized, as suggested by Spinner et al. In this study, preoperative MRI studies showed an epi- or interfascicularly spreading cyst or a combination of both.[11] We hypothesize that if an interfascicular cyst is found at the medial side of the peroneal nerve where the articular branch is usually located, a hypoechogenic ring structure can be found in the postoperative nerve ultrasound. Therefore, we interpret this mor-

phological alteration as a remnant of the decompressed cyst.

In cases in which a hypoechogenic ring structure is not detected with postoperative neurosonography, there might be a spreading epifascicular cyst, so that decompression could result in cyst collapse and its adherence to the outer epineurium. These findings may not be detected with nerve ultrasound.

Nevertheless, one of our patients (patient 14, Fig. 5) did not recover after 2 months, although a hypoechogenic ring structure with relaxed fascicles was detected. This patient was lost to further follow-up. An extensive retrospective analysis of patient outcome after surgical treatment of an intraneural ganglion cyst reported by Wilson et al.[16] showed the important role of long-term follow-up, especially in regard to motor function recovery. Based on those data, it seems to be reasonable that further motor recovery might be expected in this case.

Comparing hypoechogenic ring structure with alteration in traumatic nerve injury, no hyperechogenic structure was observed within the nerve, a finding also described by Koenig et al.[6] in cases of intraneural fibrosis, neuroma, or partial neuroma. Moreover, typical signs of tumor lesions, such as bloated fascicle structures with or without hypervascularization and hyperechogenicity,[9] are missing in our ultrasound examination. Finally, the hypoechogenic ring structure is located in the area of surgical treatment and does not skip nerve compartments or nerve sections without significant enlargement of the nerve that is typically seen in demyelinating or inflammatory neuropathies.[3,8,10,14]

All morphological findings taken together suggest that the hypoechogenic ring structure might constitute a relaxed and collapsed cyst remnant.

Limitations of This Study

This was a single-center retrospective study with a small cohort of patients who underwent a postoperative nerve ultrasound examination following decompression of an intraneural ganglion cyst. Therefore, preoperative nerve ultrasound is missing in this trial, so there is limited evidence relating to fascicular structure and cyst formation preoperatively. Thus it was not possible to directly compare postoperative images to preoperative images. Furthermore, postoperative MRI was not performed at the time of ultrasound examination and this may be a useful addition or alternative for assessing intraneural structures.

Conclusions

Recovery of muscle function after decompression of intraneural ganglion cysts of the CPN is satisfactory in most patients. An intraneural hypoechogenic ring structure in postoperative nerve ultrasound examination correlates well with good recovery of impaired motor function after surgical treatment of intraneural ganglion cysts of the CPN, whereas progress of hypesthesia and development of pain postoperatively did not seem to be correlated with intraneural structural findings in postoperative nerve ultrasound examination in our study. Further prospective studies encompassing prospective ultrasound examination of a larger cohort are needed to confirm our results, but intraneural hypoechogenic ring structure in postoperative nerve ultrasound might become a prognostic factor for good clinical outcome.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Antoniadis. Acquisition of data: Knoll. Analysis and interpretation of data: Knoll, Pala, Antoniadis. Drafting the article: Knoll. Critically revising the article: Knoll, Pala, Pedro, König, Antoniadis. Reviewed submitted version of manuscript: Pala, Pedro, Bäzner, Schneider, König, Wirtz, Antoniadis. Approved the final version of the manuscript on behalf of all authors: Knoll. Statistical analysis: Friedrich, Pauly. Administrative/technical/material support: Pedro. Study supervision: Antoniadis.

Supplemental Information

Previous Presentations

Portions of the ultrasound results were presented at the 2nd German South American Meeting of Peripheral Nerve Surgery (GERSAM) in Rio de Janeiro, Brazil, November 2017; the German Neurosurgery Society (DGNC) annual meeting, Magdeburg, Germany, May 2017; and the European Association of Neurosurgical Societies (EANS) annual meeting, Brussels, Belgium, October 2018.

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