Research article

The prevalence of carpal tunnel syndrome among long-term manual wheelchair users with spinal cord injury: A cross-sectional study

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Context: Use of a handrim wheelchair could force the wrist into extreme excursions and encroachment of the median nerve.
Objective: We performed a study of the prevalence of carpal tunnel syndrome in prolonged wheelchair users.
Design and setting: A cross-sectional study was conducted for one year in an outpatient clinic of spinal cord injury.
Participants: Patients had traumatic injury at the first thoracic level and below, with time since injury of at least 5 years.
Outcome measure: The prevalence of carpal tunnel syndrome by history taking, clinical examinations and motor and sensory nerve conduction studies of median nerve performed for both hands.
Results: Participants (N = 297) were all male. Mean (SD) age and duration since injury were 48 (8.5) and 23 (6.6) years, respectively. A significant difference in median duration of injury based on the severity of the syndrome ($P < 0.001$), and a significant trend in time since injury for the severity (P (one tailed) < 0.001) were seen. There was a significant difference in the median age among the groups ($P = 0.009$), and the median increased with the severity (P (one tailed) $= 0.001$).
Conclusions: Carpal tunnel syndrome is a common side effect of the long time use of wheelchair, and its severity is associated with duration of wheelchair use and age. Alternative methods for wheelchair propulsion should be developed to diminish the likelihood of the syndrome.

Keywords: Carpal tunnel syndrome, Wheelchair, Spinal cord injury, Electrodiagnostic study, Median nerve

Introduction

Carpal tunnel syndrome (CTS) has been reported in 49–73% of manual wheelchair users with spinal cord injury.[1–3] Wheelchair users rely on their arms for usual activities, including locomotion and weight-bearing. Repeated manual activity exacerbates the disease severity.[1] The resulted pain limits most activities of daily life and increases dependence on helpers.[4] The diagnosis is based on the presence of symptoms, physical findings, positive nerve conduction studies and provocative tests such as Tinel's, and Phalen's signs, taken together.[5,6–11] The clinical diagnosis is most commonly confirmed by electrodiagnostic (EDX) studies as the reliable, differentiating, and the most objective diagnostic test.[5,6,9,12,13] Severity of carpal tunnel syndrome can also be evaluated by EDX, done bilaterally.[14]

Repetitive strain and overuse of the wrist flexor tendons has been suggested as the cause of inflammation and eventually encroachment of the median nerve in wheelchair users.[15,16] Evidence suggests that older age, female gender, length of time since injury, and greater body mass index are other independent potential risk factors for CTS.[4] Some conditions have been reported to be associated with the syndrome, such as rheumatoid arthritis, hypothyroidism, diabetes mellitus, alcoholism, pregnancy, and previous hand surgery.[5] Moreover, entities like polyneuropathy, radiculopathy, motor neuron disease, spondylotic myelopathy, syringomyelia, and multiple sclerosis should be differentiated from CTS.[17]

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There are limited observational studies on the prevalence of, or the risk factors associated with CTS in users of wheelchair. Moreover, the exact prevalence of CTS attributable to the use of handrim wheelchair is difficult to elucidate due to different diagnostic procedures, subjectivity of the diagnostic criteria, sex difference, diversity of the causes of wheelchair use and spinal cord injury, difference in patients' education for proper use of wheelchair, severity of CTS, small sample size, and shortness of time since injury. To assess the impact of wheelchair use over the long term the effect of the confounding variables should be minimised. Few studies had sufficient power to study the association between duration of spinal cord injury and CTS severity. In addition, methodological and statistical shortcomings have led to conflicting results.

Research studies reported various percentages as the prevalence of CTS in users of wheelchair; 50%,[3] 52%,[18] 63%,[1] and 78%.[4] Some studies indicated that there is no association between the prevalence; and age[2,19] or time since injury.[2] While some others found associations in terms of duration of symptoms.[1,4,19] Previous studies included different sample sizes from 23 patients[19] to 126 participants[4] and therefore had considerable uncertainty around the prevalence of CTS in long-term wheelchair users, reflected in the wide range of the estimates. Therefore, to estimate the prevalence of CTS and to assess the impact of using wheelchair over the long term in paraplegic patients a large study is still required.

We performed a study of the prevalence of CTS in a large sample of patients who have used their hands extensively for daily activities. We tried to minimize the effects of confounders by choosing objective criteria for diagnosing and specifying severity of CTS, and by selecting a large and relatively homogenous sample containing male Iranian veterans with spinal cord injuries mainly due to shrapnel. Our patients had not attended any special training or educational program for proper wheelchair use. Also, they were long-term users of almost the same type of wheelchair. We also studied the association between age, duration of spinal cord injury and CTS severity, and investigated if there are any trends in age and time since injury for the severity of CTS. The hypotheses were that wheelchair use would be associated with CTS, and that the severity would be related to time since injury.

Patients and methods

Design and setting

We performed a single group cross-sectional study. The study was conducted from March 2012 to February 2013 in an outpatient clinic of spinal cord injury at a Neuroscience Research Centre of a large referral practice and subspecialty hospital.

Recruitment

We recruited manual wheelchair users with spinal cord injury. Most of the participants were Iranian veterans of war (1980–1988). Patients' name and address were obtained from the hospital records. A study nurse phoned and invited patients to attend the spinal cord injury unit.

Participants

Before the start of recruitment, attending physicians and research nurses were briefed.

The assessors who performed physical examination and the investigators who carried out EDX studies had received extensive training. Patients were commonly using classic hospital-type wheelchair. These wheelchairs are high weight and poor performance, and require the user to move his arms clumsily and employ great force at the push-rim for needed maneuvers. Participants attended for two visits.

At the first visit, patients were screened for eligibility. Information on the characteristics of patients, including demographic data and medical histories was obtained by two general practitioners. Participants filled in a questionnaire on risk factors for CTS. At this stage, general physical examinations were performed. Of the 421 potential eligible patients 26 refused to participate, and 395 completed visit one. From this population, after excluding 34 patients, 320 participants were randomly selected. Then, selected patients were invited to attend visit two. Twenty-three participants did not attend the second visit. At the second visit, 297 patients underwent more advanced clinical examinations and diagnostic procedures for the detection of CTS. At this stage, the clinical assessors were board-certified physical medicine and rehabilitation specialist.

Inclusion criteria

We included male manual wheelchair users if they had traumatic spinal cord injury at the first thoracic level and below with time since injury of at least 5 years. Participants were eligible if they were at least 20 years of age, with average daily use of a manual wheelchair more than 40 hours a week.

Exclusion criteria

We confined our sample to male participants because we preferred to cancel out the effect of sex on the prevalence and severity of CTS, and basically we have only male veterans in Iran. Also, we tried to confine our analytic

sample to the patients without potential risk factors of CTS other than wheelchair use. Recruited participants were screened to ensure that they had no history of local injuries including: upper-limb trauma and previous surgery, tenosynovitis, hemangioma, cyst, ganglion, lipoma, neuroma, thickened transverse carpal ligament, or bony abnormalities. Patients with manifestations of osteoarthritis, rheumatoid arthritis, amyloidosis and gout were excluded from the study. Likewise, participants were examined for the presence of systemic causes of CTS, and excluded if they had diabetes, hypothyroidism, renal failure, and autoimmune diseases, or excluded if they were undergoing hemodialysis. We did not enter participants with body mass index more than 30 kg/m^2 into the study and did not enter patients with heavy occupational activities like computer use that would increase the likelihood of developing CTS. In addition, we excluded individuals if they could not tolerate the EDX study.

Of the 34 excluded patients 29 had diabetes, 3 had body mass index more than 30 kg/m^2, 2 were heavy computer users, 4 had previous history of upper-limb trauma or surgery, 1 had rheumatoid arthritis, and 1 was undergoing hemodialysis. Some participants met a combination of exclusion criteria.

Randomization and blinding

Based on computer-generated random numbers, we selected our analytic sample from the included participants who completed the second visit. The investigators who performed EDX studies were blinded to the study question, and to patients' detailed medical history. The clinical assessors for visit two were unaware of the results of the previous visit. With the purpose of being assured that the measurement process itself does not lead to bias, we used a block design to randomise the patients to observers.

Protocols and procedures

History was recorded by interview and self-administered questionnaire pertaining to demographic, lifestyle, and comorbid conditions. Dominant hand, the presence of numbness, tingling, and pain with wheelchair propulsion were also recorded. In addition, the recruitment questionnaire asked about consultation with a physician and active treatment. For the second visit, our specialists completed a detailed medical history, performed physical examinations and conducted further investigations for the diagnosis of CTS. Duration, severity, worsening at night, and location of symptoms were noted.

Physical examinations for visit two included: observation of deformity, sensory, and motor examinations, muscle testing for atrophy (e.g. abductor pollicis brevis) and weakness, range of motion for the wrist and digit, provocative tests (Tinel's and Phalen's sign), and discriminatory examination of the upper extremity and neck that might related to the alternative diagnoses. Radiographs of the wrist were obtained if needed.

Motor and sensory NCS of median and ulnar nerves were performed for both hands. For motor NCS, the median and ulnar motor nerves were stimulated at wrist, 8 cm proximal to the active recording electrode. The motor conduction for median and ulnar nerves was performed using the surface electrodes over abductor pollicis brevis (APB) and abductor digiti minimi, respectively. The stimulation was done at 8 cm proximal to active electrode.

The sensory responses were obtained at the third and fifth digits for the median and ulnar nerves, stimulating antidromically at 14 and 11 cm respectively. We considered median motor latency less than 4.1 ms, and median sensory distal peak latency less than 3.6 ms, as the normal values. We used a bandwidth setting of 20 HZ to 3 KHz (3 to 20 KHz), sweep speed 1 msec/division and gain 10 to 20 μV/cm. The skin temperature of the forearm and wrist were kept at 32–33°C during all measurements.

Ethical considerations

Ethics approval was obtained from the institutional review boards, and the study protocol was carried out in accordance with the Declaration of Helsinki. The rationale of the study was explained to all participants. Patients were informed that they were free to withdraw from the study at any time. A study nurse accompanied and provided patients with verbal information and a leaflet on the diagnostic procedures. All patients gave written informed consent at the beginning of the first and second visits and did not pay for the diagnostic procedures. They were referred to other departments for appropriate treatment, if needed.

Sample size

Sample size calculations were based on the formula: $N = 4\left[\frac{pq}{\omega^2}\right]z^2_{1-\alpha/2}$, where p is the anticipation of the prevalence of CTS; $q = 1\text{-}p$; ω is the planned width of 95% CI for the estimation of the prevalence, $\alpha = 0.05$, and $z_{0.975} = 1.9600$. Different prevalence rates for CTS, confirmed by electrophysiologic studies, have been reported in the literature: 63%,[1] 70%,[7] and 78%.[4] For the anticipated prevalence of 70%, we were able to include 297 participants to provide the planned width $\omega \approx 0.1$ of 95% CI for the estimation of the prevalence.

Statistical analyses

Participants were stratified by CTS severity, according to the American Association of the Electrodiagnostic Medicine criteria[20] as mild: prolonged sensory distal latency more than 3.6 ms with or without sensory nerve action potential amplitude below the lower limit of the normal; moderate: abnormal median sensory latency as above, and prolongation of median motor distal latency (Sensory distal latency more than, or equal to 3.6 ms, motor distal latency more than 4.1 ms); severe: prolonged median motor and sensory distal latencies with either an absent sensory nerve action potential or low-amplitude or absent thenar compound muscle action potential.

The severity of CTS was treated as an ordered categorical data.

We measured the strength of linear relationship between severity of CTS and duration of injury with Pearson's correlation coefficient. We used ANOVA test for comparing the groups normal, mild, and combined severe-moderate CTS in the mean duration of injury. Kruskal–Wallis test was applied to determine if there is significant difference in median duration of injury and median age among the severity groups of CTS. For assessment of trends Jonckheere-Terpstra test for trend was used. Trends were evaluated for the severity CTS with respect to time since injury and age. Data were analyzed with a statistical software package (SPSS for Windows, version 11.5, SPSS, Inc., Chicago, IL, USA). A P-value of less than 0.05 was considered significant, and the power of statistical tests was set at 80%.

Results

The analytic sample was composed of 297 participants (594 hands). They ranged in age from 20 to 69 years, with a mean (SD) age of 48 (8.5) years. Mean duration of injury was 23 (6.6) with the range of 5 to 31 years. The distribution of time since injury was skewed to the left (skeweness = –1.3, median = 25 years, interquartile range = 5 years) (Figure 1). Of the participants, 93.6% were right hand dominant. The most frequent cause of injury was shrapnel (42.2%).

Of these participants, 192 (64.6%) had clinical symptoms consistent with CTS, while 212 (71.4%) showed EDX evidence of CTS. Of the patients with CTS, 158 (74.5%) showed bilateral evidence in the EDX study, and 192 (90.6%) had dominant hand involvement. Figure 2 and Table 1 show the duration of spinal cord injury for the study sample, according to the severity of CTS.

The distribution of the duration of injury in each group was not Normal ($P < 0.001$). There was a

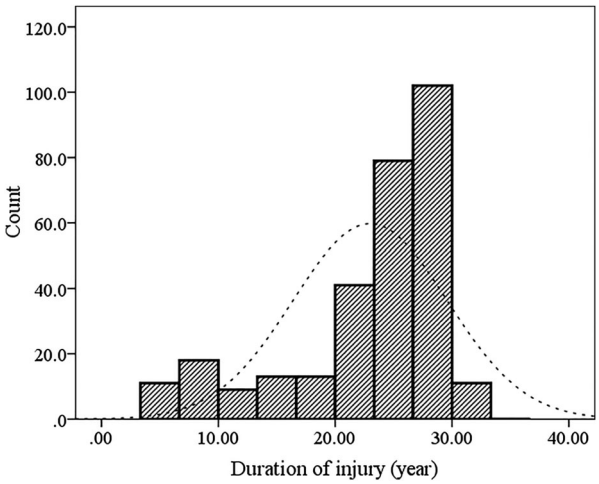

Figure 1 Histogram of the duration of injury for all participants. Dotted line indicates Normal distribution.

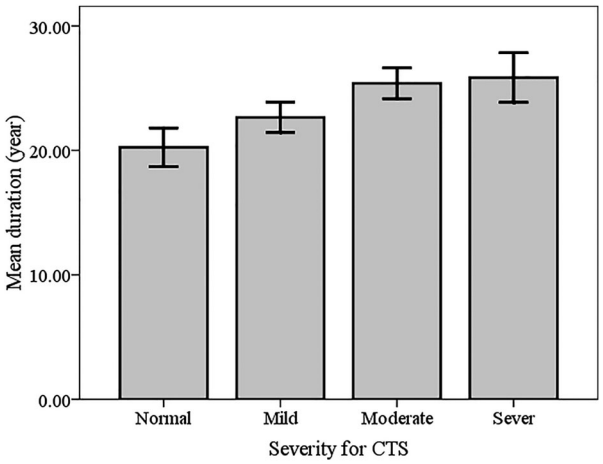

Figure 2 Mean duration of injury, based on the severity for CTS. Error bars represent 95% CI for mean.

Table 1 Descriptive results for the duration of injury, based on the severity for CTS

	Severity of CTS			
	Normal	Mild	Moderate	Severe
Number (%)	85(29)	107(36)	72(24)	33(11)
Mean (year)	20.2	22.6	25	25.8
95% CI for mean (year)	18.7 to 21.8	21.4 to 23.9	24.1 to 26.6	23.9 to 27.8
Median (year)	22	24	27	27
Standard deviation (year)	7.2	6.3	5.2	5.6
Minimum (year)	5	6	5	7
Maximum (year)	31	29	29	31
Interquartile range (year)	10	5	2.7	5
Skewness	−0.5	−1.5	−2.7	−2.4

statistically significant difference in the median duration of injury based on the severity of CTS (Kruskal–Wallis $H(3) = 44.77$, $P < 0.001$). In addition, Jonckheere-Terpstra test for trend revealed a significant trend in time since injury for the severity of the syndrome: as the median of time since injury increases with the severity of CTS [$J = 21420$, $z = 6.88$, Monte Carlo P (one tailed) < 0.001]. For the *post hoc* tests, we performed Mann-Whitney tests with Bonferroni correction for the 6 comparisons among the groups normal, mild, moderate, and severe (level of significance $= 0.05/6 = 0.008$). It appeared that the duration of injury was not different between the groups moderate and severe ($P = 0.325$), and between the groups normal and mild CTS ($P = 0.008$). Other comparisons were statistically significant ($P < 0.001$).

To increase cell sizes, we combined groups moderate and severe CTS ($N = 72 + 33 = 105$), and performed ANOVA test. Levene's test indicated that the homoscedasticity of the model was violated [$F(2,294) = 9.97$, $P < 0.001$]. Therefore, Games-Howell adjustment was used for *post hoc* multiple comparisons. The ANOVA test showed a significant difference between the groups normal, mild, and the combined severe-moderate CTS [$F(2,294) = 16.87$, $P < 0.001$] in the duration of injury. Post-hoc tests indicated that there were significant differences between normal and combined moderate-severe ($P < 0.001$), and between mild and combined moderate-severe CTS ($P = 0.001$) groups. Also, polynomial linear trend test demonstrated a significant trend [weighted linear $F(1,294) = 33{\cdot}64$, $P < 0.001$].

Table 2 shows the descriptive results for age. The distributions of age were not normal among the severity groups ($P < 0.001$ for normal, mild CTS, moderate CTS, and $P = 0.037$ for severe CTS). The Kruskal–Wallis test indicated that there was a statistically significant difference in the median age among the severity groups of CTS (Kruskal–Wallis $H(3) = 11.79$, $P = 0.009$). The Jonckheere-Terpstra test indicated a significant trend in age for the severity of CTS, as the median age increases with the severity of the syndrome [$J = 18050$, $z = 2.74$, Monte Carlo P (one tailed) $= 0.001$]. Pairwise comparisons with Mann-Whitney tests and Bonferroni correction (level of significance $= 0.05/6 = 0.08$) revealed that age was significantly different between groups normal and moderate CTS, and between mild and moderate CTS ($P = 0.001$, and $P < 0.001$, respectively). Other comparisons were not statistically significant ($P \geq 0.2$).

Table 2 Descriptive results for age, based on the severity for CTS

	Severity of CTS			
	Normal	Mild	Moderate	Severe
Mean (year)	45.7	47.5	53.1	48.4
95% CI for mean (year)	43.8 to 47.7	46.0 to 49.2	49.4 to 53.2	46.2 to 50.5
Median (year)	47	47	48.5	48
Standard deviation (year)	9.0	8.5	7.9	6.1
Minimum (year)	21	20	39	41
Maximum (year)	69	65	68	61
Interquartile range (year)	6	9	12	8
Skewness	−0.5	−0.3	0.65	0.73

There was a significant correlation between severity of CTS and duration of injury (Pearson's correlation coefficient $r = 0.31$, $P < 0.001$). We also conducted a partial correlation between the severity of the syndrome and duration of injury while controlling for the effect of age. The correlation was still significant ($r = 0.27$, $P < 0.001$).

Discussion

In this study we intended to estimate the prevalence of CTS among the population of prolonged wheelchair users. In addition, we tried to investigate if there is an association between the time since injury or age, and the severity of the disease. The results indicated that CTS is a common side effect of manual wheelchair use, and EDX study increases the frequency of clinically diagnosed CTS. Most of the patients with CTS had bilateral and mild form of the disease. Dominant hands were more commonly involved, as well. Overall, these findings are consistent with previous studies.[1,2,4–7,18–21]

The results showed that there is a significant trend in time since injury for the severity of CTS. In other words, more prolonged use of manual wheelchair is associated with more severe forms of CTS. The difference is obvious, as well, when the participants were categorised into two classes; group normal or mild, and group moderate or severe CTS. Likewise, our findings implied that there is a trend in age among the groups of CTS severity. The analyses showed that the correlation between the severity of CTS and time since injury is independent of age. This could be due to the fact that time since injury is a surrogate to the overall magnitude of wheelchair use. Age was significantly different between groups normal and moderate CTS, and between mild and moderate CTS. It seems that, severe CTS is more related to wheelchair use rather than old age.

Our sample was a relatively homogeneous population of patients, and was sufficiently large to detect important differences between the groups. Mean age and

time since injury were high and the distributions were left skewed. This may be explained as recruiting a large number of the war veterans. These advantages, in addition to the extensive use of randomisation enabled us to identify the differences and trends more easily, and to reduce the possibility of selection bias. Our research team and assessors were highly trained, and they attempted to follow the diagnostic protocols strictly.

In a research study on compressive mononeuropathies of the upper extremity in chronic paraplegia, 31 patients with a mean time since injury of 9.7 years (range 1–28 years), were studied. The researchers of that study concluded that there was no association between prevalence of compressive mononeuropathies and age of the patient or time since onset of injury.[2] In an assessment of motor deficits in nine healthy participants, eight patients with mild, and six individuals with severe CTS, no differences in the median age or sex among the groups were found.[19] However, the small sample size may be an indication that those studies were inadequately powered to detect clinically important effects. Also, our sample had higher mean age and higher mean time since injury. In an electrodiagnostical study of thirty-three world-class wheelchair basketball the prevalence and the severity of median neuropathy were estimated. Thirty percent of the participants had symptoms consistent with CTS, and 70% had EDX confirmation of the disease. Overall, 52% of the 33 athletes had EDX findings of median neuropathy at the wrist with nine athletes (27%) exhibiting bilateral abnormalities.[18]

In a cross-sectional multicenter study, 126 manual wheelchair-users with chronic paraplegia underwent physical examination specific for CTS.[4] Mean (SD) duration of injury was 13.2 (9.0) ranging from 1.2 to 34.4 years. Most of the patients had midlevel paraplegia with lesions especially at the level of T12. The researchers of that study had used Boston Carpal Tunnel Questionnaire to assess CTS symptom severity and functional status. The questionnaire has not been validated specifically for use in persons with spinal cord injury. Their results indicated that 78% of patients had electrophysiologic evidence of median mononeuropathy. In addition, they reported that those with physical examination findings were more likely to have longer duration of injury ($P = 0.003$). Our descriptive results are consistent with these findings, and are similar to the ranges reported previously. Meanwhile, in our study, the sample was larger; standard deviations were smaller; and obviously our patients were more prolonged users of manual wheelchair. We used objective criteria for classifying the severity of CTS, as well.

Limitations

To minimise the potential for confounding by the risk factors, we limited the analysis to non-obese male participants. This may reduce the generalizability of the results. Meanwhile, it should be emphasised that we were trying to investigate some controversial trends; and that female sex and high BMI are relatively well known risk factors. We did not addressed movement pattern difficulties and wheelchair ergonomic defects. Also, we did not examine the impacts of other risk factors including diabetes on the development of CTS.

Clinical implications

Our study has some implications for the management of the patients with chronic paraplegia. Hospital-type wheelchairs cause repetitive strain injury when used in the long term. Application of light wheelchairs with lower rolling resistance and educating patients how to prevent cumulative trauma may decrease the risk of the injury. For patients with long-term wheelchair use, EDX study should be considered. Also, we recommend periodic evaluation of patients for CTS, especially in the presence of other local or systemic risk factors. The concurrence of other risk factors such as diabetes may cumulatively increase the probability of CTS and the physician is supposed to be aware of the syndrome even when the symptoms are not strongly indicative. Further research studies are required to investigate these issues.

Conclusion

Carpal tunnel syndrome is a common side effect of manual wheelchair use. Typically, patients have mild and bilateral form of the disease. Prolonged use of wheelchair is associated with more severe forms of CTS. There is a trend in age and time since injury among the groups of CTS severity. Severe CTS is more related to wheelchair use rather than old age.

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Disclaimer statements

Contributors MA designed the study, guided the development of the study protocol, reviewed the literature and participated in interpretation of the results and drafting the manuscript. MTH participated in interpretation of the results, and critically reviewed the manuscript. TT contributed to the planning and conduction of the study, and wrote the 'Discussion' of the draft. HK coordinated the research, analyzed the study data,

prepared tables and figures, and wrote the 'Results' of the draft. AKA contributed to the planning and participated in drafting the 'Patients and methods' section. All the authors have contributed to and approved the final version of this manuscript.

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Conflicts of interest The authors declare that they have no competing interests.

Ethics approval Ethics approval was obtained from the institutional review boards, and the study protocol was carried out in accordance with the Declaration of Helsinki. The rationale of the study was explained to all participants. Patients were informed that they were free to withdraw from the study at any time. A study nurse accompanied and provided patients with verbal information and a leaflet on the diagnostic procedures. All patients gave written informed consent at the beginning of the first and second visits and did not pay for the diagnostic procedures. They were referred to other departments for appropriate treatment, if needed.

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