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Full Length Research Paper

The efficacy of 0.2 T low-field open MR imaging in the diagnosis of carpal tunnel syndrome

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The aim of this study was to image the morphologic changes that take place in the wrists of patients who had been diagnosed with carpal tunnel syndrome (CTS) and define certain magnetic resonance imaging (MRI) findings that could be characteristic for the diagnosis of CTS, without the need of going for electrodiagnostic modalities such as electromyography (EMG). We also had the intention to investigate the efficiency of 0.2 T low-field MR imaging in the diagnosis of CTS. The 52 patients who were included in this study were selected from those who had applied to the Orthopedics Department of our hospital and were diagnosed with CTS. The patients had positive EMG results, and they had no history of surgical intervention or trauma. MRI examinations were performed in a 0.2 T low-field open scanner. The most frequent morphological change encountered in CTS is diffuse or local swelling and flattening of the nerve which occurs while it traverses the carpal tunnel. Thus, the most prominent MRI finding of CTS encountered in this study was high signal intensity along the median nerve tract detected at short time inversion recovery (STIR) sequences. Another finding was flattening of the nerve tract and increase in its diameter. In addition to this finding, there was also palmar bowing at the flexor retinaculum. Based on our observations, we conclude that the first diagnostic modality should be MRI in patients who are suspected to have CTS according to their histories and clinical examination findings. We conclude that EMG should be reserved as a secondary diagnostic tool when MRI findings are negative or suspicious. We also emphasize that detailed anatomic data supplied by MRI is of utmost importance for the reliability of both the surgical intervention itself and postoperative follow-up.

Keywords: Carpal tunnel syndrome, median nerve, MRI

INTRODUCTION

Carpal tunnel syndrome (CTS) is a constriction neuropathy of the median nerve along the nerve's path through the carpal tunnel (Mumenthaler et al, 1991). CTS is the most frequent of all the median nerve lesions (Adams et al, 1993). It is also the most frequently encountered trap neuropathy (Donaldson et al, 1992; Patent et al, 1996)). Its prevalance is reported to be 3.72

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% (Papanicolau et al, 2001). It is most frequently seen between 40-70 years of age, and is encountered 5 times more frequently in females than males (Mumenthaler et al, 1991). The syndrome is more frequent in the dominant hand, but 50 % of cases present with bilateral affection (Szabo et al, 1992). The following are among the risk factors which contribute to the development of CTS: age, gender, obesity, smoking, caffein and alcohol intake, severity of exercise, and use of oral contraceptives (Stallings et al, 1997).

CTS was first defined by Sir James Paget in 1853, and the first surgical treatment was conducted by Learmounth in 1933 (Szabo et al, 1992; Erdmann et al, 1994; Evans et al, 1994). CTS was defined as the most frequent etiological factor of median neuropathy after Phalen's publication about the issue in 1950 (Phalen et al, 1950). In 1976, Sunderland published a paper and indicated that CTS developed basically due to the increase in tunnel pressure. Sunderland emphasized that this pressure gradient restricted venous return, and this in turn led to intrafunicular anoxia, which gave way to the development of edema. This edema, according to Sunderland, was responsible for the increased pressure gradient and compression effect on the median nerve (Sunderland et al, 1976).

Several etiological factors have been reported for the development of CTS, including systemic and in-canal processes. Any process which restraints the carpal tunnel or increases its inner pressure may lead to the trapment of the median nerve (Masgarzadeh et al, 1995). The following may be listed among the etiological factors: acute processes such as abscesses, wrist fractures, and in-canal bleeds; and chronic processes such as connective tissue diseases, mass effects caused by space-occupying mass lesions, and edema due to hypothyroidism and pregnancy. But still in most of the cases the etiological factors are not fully understood, and 43 % of cases are accepted as idiopathic (Mumenthaler et al, 1991; Erdmann et al, 1994; Nakamichi et al, 1993; Semer et al, 1989).

The diagnosis of CTS is established clinically (Masgarzadeh et al, 1995; Kulick, 1996, Finsen et al, 2001; Bagatur et al, 2001). The clinical neurological examination and electrodiagnostic test findings are fundamental in the diagnosis. CTS becomes clinically evident when the patient starts to experience the symptoms of paresthesia, pain, and sensory and motor loss in the median nerve area, which exacerbates during the night time. The disease leads to tenar muscle atrophy during its advanced stages. Among the findings that contribute to the diagnosis of CTS are positivity of the Tinel and Phalen tests, tenar atrophy, and neural conductivity compromise (Davis, 1998).

Neural conductivity studies constitute an important place in the electrodiagnostics of CTS. These studies are the gold standard of CTS diagnosis, and their sensitivity and specificity are 49-84 % and 94-99 %, respectively (Sen et al, 2002). But these findings may be mistaken for other disorders such as cervical root impingement, thoracic outlet syndrome, and other various peripheric nerve impingement syndromes (Ebstein et al, 1989; Gazzer et al, 1984). This is why a lot of studies are being conducted in order to investigate the efficiency of radiological modalities for defining the etiological factors of CTS and demonstrate the morpholgic changes it causes in the wrist. Even though conventional radiography is the modality of choice in the investigation of the general bone structures of the wrist, it is insufficient in the detection of the subtle bony changes and soft tissue alterations that take place in and around the carpal tunnel. By utilizing high-resolution ultrasound (US), alterations in the median nerve diameter and palmar bowing at the flexor retinaculum may be demonstrated (Nakamichi et al, 1993).

Thin-slice computed tomography (CT) may be helpful in the quest to investigate the anatomic structures that constitute the carpal tunnel, together with the morphological changes that take place in the process of CTS. CT is especially effective in bone imaging. But it is not as effective in the imaging of the soft tissues (Gazzer et al, 1984). Magnetic resonance imaging (MRI) has the highest sensitivity and specificity in the diagnosis of CTS (Browning, 2004). MRI is a very valuable tool in the imaging of the carpal tunnel because of its supreme soft tissue resolution (Rosenbaum, 1993; Siegel et al, 1996; Socetti et al, 1992; Radack et al, 1997).

The median nerve has a medium signal intensity like the muscles. This makes it easier to distinguish it from the tendons which exhibit lower signal intensities (Totterman et al, 1993). The nerve passes just beneath the flexor retinaculum and appears as a thickened structure at the level of the hamatum hook.

Below is the list of the MRI findings encountered in patients diagnosed with CTS (Socetti et al, 1992; Radack et al, 1997; Middleton et al, 1987; Horch et al, 1997).

1- High signal intensity at the median nerve path on T2-weighted series

2- Flattenning of the median nerve (especially at the level of the os hamatum)

3- Diffuse or segmental increase of the diameter of the nerve (best visualized at the os pisiform level)

4- Palmar bowing (best apparent at the os hamatum level)

Our purpose in this study was to image the morphologic changes that take place in the wrists of patients who had been diagnosed with CTS, following clinical and electrodiagnostic procedures. We also had the intention to investigate the efficiency of 0.2 T low-field MR imaging in the diagnosis of CTS.

	Number of Patients	Min.	Max.	Average	Standard Deviation
AGE	86	27	69	45,40	10,538

Table 1. Age distribution and mean age

MATERIALS AND METHODS

This study was conducted at the Radiology Department of the Numune Teaching and Research Hospital, Adana, Turkey. 52 patients who had applied to the Orthopedics Department for pain in their wrists were included in the study. The study was approved by the investigational ethics review board of the hospital and conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from every patient prior to the MR examination. These patients underwent an MR examination of their wrists. 86 wrists belonging to the 52 patients were examined for any MR sign which could prove to be effective in the defining of CTS. The ages of the patients ranged between 27 and 69 years. The median age was 45 years (Table 1)

The patients who were included in this study were selected from those who had applied to the Orthopedics Department of our hospital and had been diagnosed with CTS. The patients had positive EMG results, and they had no history of surgical intervention or trauma. MR examinations were performed in a 0.2 T low-field open scanner.

MR examinations started with a two-dimensional gradient recalled echo (2D GRE) coronal localizer sequence. Using this localizer sequence, axial spin echo T1-weighted (SE T1W), fast spin echo T2-weighted (FSE T2W), STIR, GRE, and coronal SE T1W sequences were obtained.

The evaluation of the median nerve was based upon the following parameters: signal increase in the median nerve path, palmar bowing at the flexor retinaculum, and flattening of the median nerve (Siegel et al, 1996; Cimen, 1991; Odar, 1988; Bonel et al, 2001).

Each wrist was accepted as an individual case. Patients with positive clinical and electrophysiological examination findings were recruited for the study. These findings, together with the positive MR findings, were enlisted in vertical columns to create a table. Positive MRI findings were as follows: signal increase in the median nerve tract, palmar bowing of the flexor retinaculum, and flattening of the median nerve. For statistical purposes, the presence of CTS was coded with 1, and its absence with 0. The patients were operated during the first three days following the MR examinations. Intraoperatively, the presence of CTS was assessed by evaluating the impingement of the carpal ligament on the median nerve, together with the formation and color of the nerve at its segments both before entering the canal and actually in it. Also, the synovia of the tendons, too, were assessed. The findings were recorded as 1 for positive, and 0 for negative. The results were evaluated by the administration of the Medcalc test, and the sensitivity of MRI in the detection of the findings of CTS was assessed.

RESULTS

52 patients, of whom 50 were females and 2 males, were included in the study. The ages of the patients ranged between 27 and 69 years, and the mean age of the group was 45 years. The patients had positive clinical and electrodiagnostic results for CTS. 86 wrists of these 52 patients were examined by MRI (Figure 4.1)

These findings were as follows: tenosynovitis in 23 (67 %) patients, tendinosis in 4 (12 %) patients, ganglion cysts in 3 (9 %) patients, carpal bone avascular necrosis in 3 (9 %) patients, and signal increase in the ulnar nerve tract in 1 (3 %) patient.

In this study, 86 cases who had been diagnosed with CTS according to their clinical and electrodiagnostic results were examined by a 0.2 T open MR scanner. At the end of the examinations, the MRI findings of 80 cases were evaluated in favor of CTS. The following findings were detected in these patients: signal increase in the median nerve tract in 80 (93 %) cases, increase in palmar bowing at the flexor retinaculum in 75 (87.2 %) cases, and flattening of the median nerve in 42 (48.8 %) cases. When these MRI findings were compared with the gold standard electrodiagnostic test results, the sensitivity of MRI was found to be 93.02 % (85.42-97.38 %), and its positive predictive value (PPV) as 100 % (95.45-10.00). Our results show congruence with the literature (Table 2)

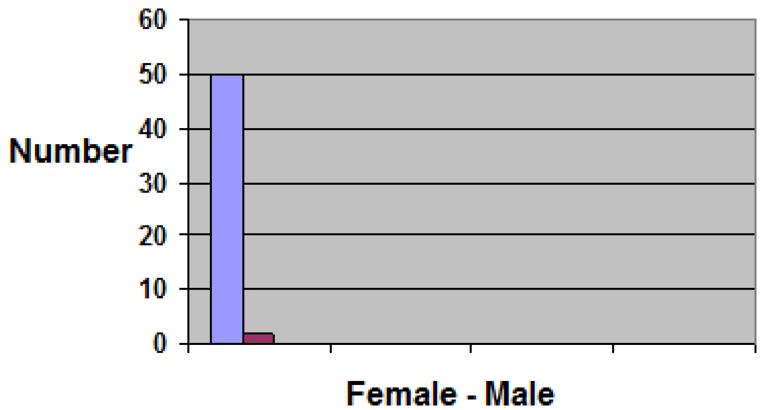

Figure 6. The distribution of the female and male patients included in the study.

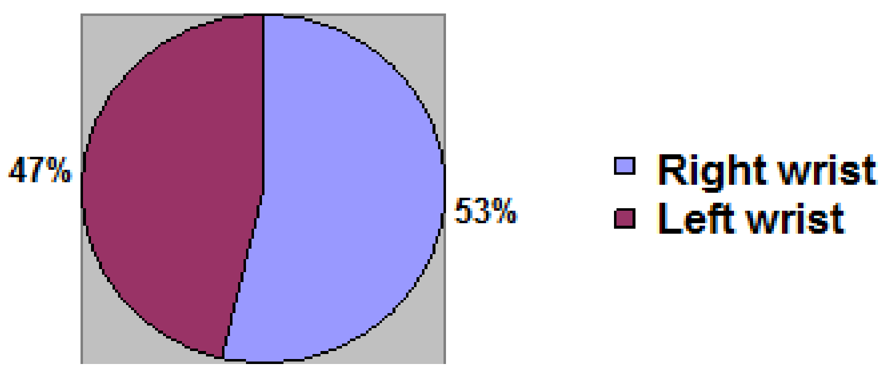

Figure 7. A total of 86 wrists, 46 (53 %) being right and 40 (47 %) left, were examined by MRI.

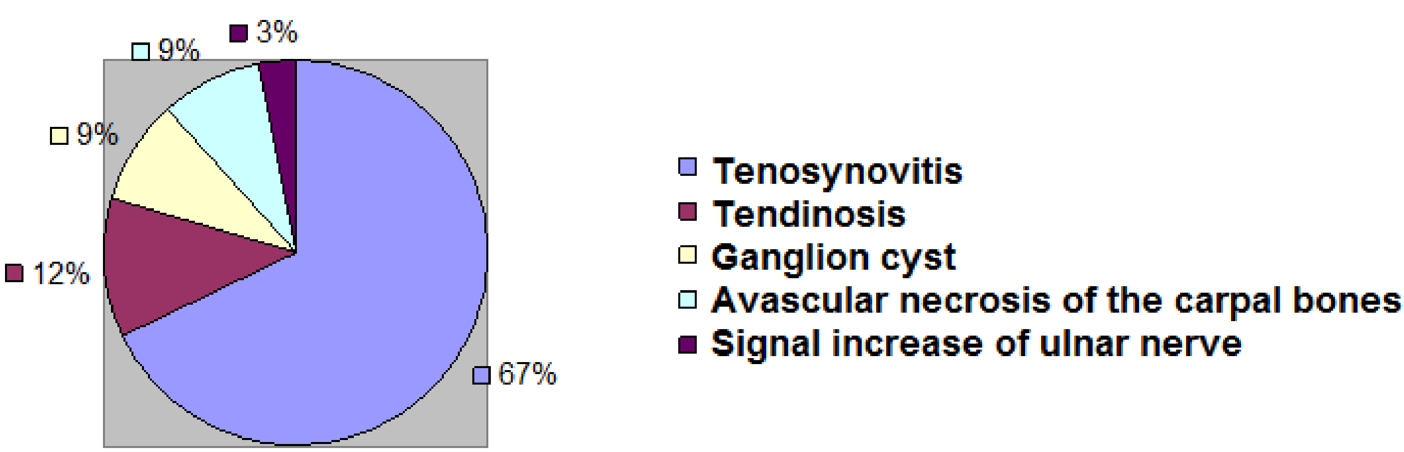

Figure 8. Some patients demonstrated additional findings in their MRI examinations.

Of these 86 wrists, 80 showed signal increase at the median nerve tract, 75 showed palmar bowing at the flexor retinaculum, and 42 demonstrated flattening of the median nerve. Among the 52 patients examined, 34 were found to have bilateral, and 18 unilateral, CTS.

The GRE image demonstrates the signal increase in the median nerve tract, while the T1W image clearly shows the flattening and increase in the nerve's diameter. In addition to this finding, there is palmar bowing at the flexor retinaculum.

			EMG	Total
			1	
MR	0		6	6
		% MR	100,0%	100,0%
		% EMG	7,0%	7,0%
		% Total	7,0%	7,0%
	1		80	80
		% MR	100,0%	100,0%
		% EMG	93,0%	93,0%
		% Total	93,0%	93,0%
Total			86	86
		% MR	100,0%	100,0%
		% EMG	100,0%	100,0%
		% Total	100,0%	100,0%

Table 2. MRI/EMG cross evaluation for CTS. CTS positivity is coded as 1, and negativity as 0.

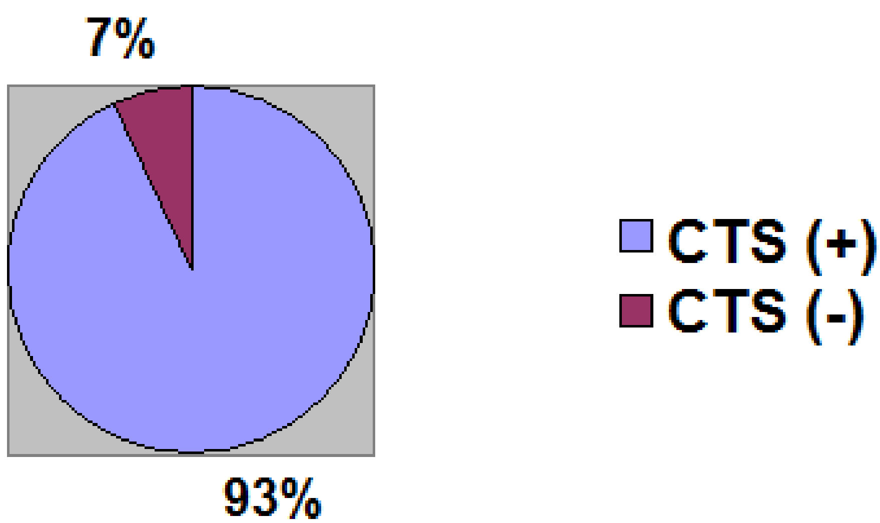

Figure 9. 86 wrists which were found to be positive for CTS based on their clinical and electrodiagnostic findings were examined by MRI and 80 (93 %) of them were found to be positive for CTS, while 6 (7 %) were negative.

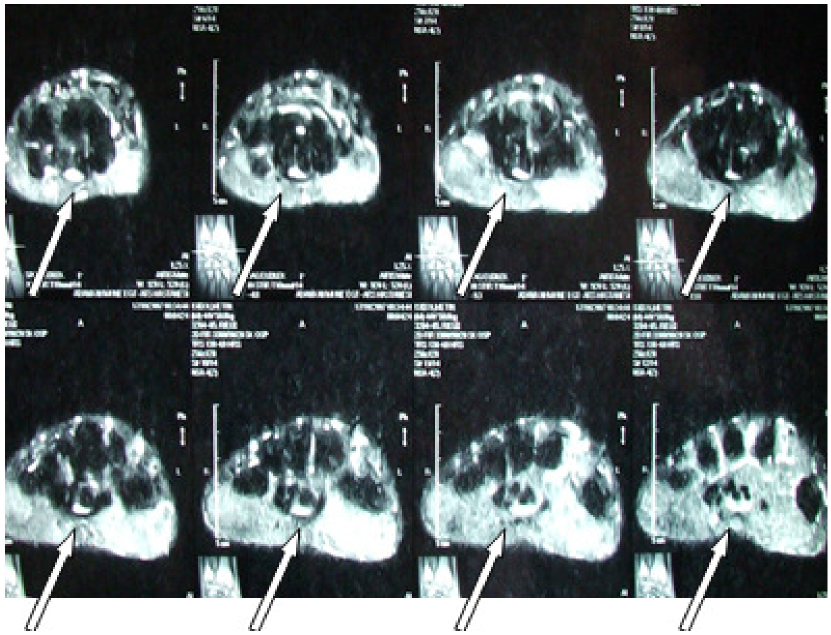

Figure 10. High signal intensity along the median nerve tract is the most prominent finding detected at STIR sequences.

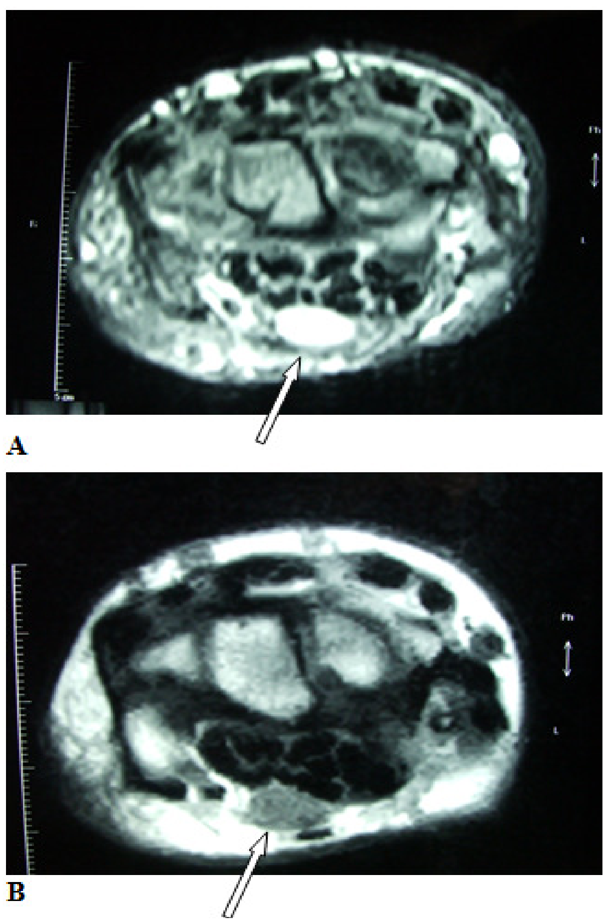

Figure 11 (A and B). Axial GRE and T1W images obtained from the proximal aspect of the carpal tunnel.

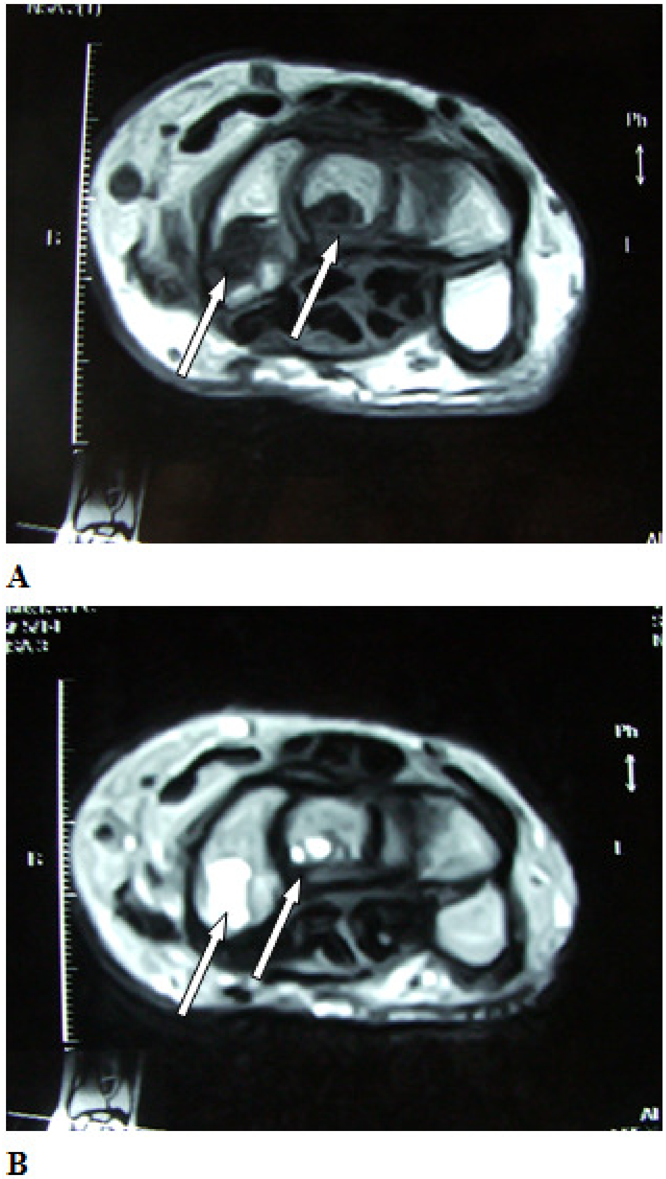

Figure 12. These axial T1W (A) and T2W (B) images demonstrate the sites of avascular necrosis (AVN) at the scaphoid and lunate bones. The AVN foci appear hypointense on T1W, and hyperintense on T2W, sequences.

DISCUSSION

CTS is the most frequent compression neuropathy of the upper extremities. CTS is characterized by the symptoms created by the chronic compression of the median nerve. Studies have showed that the prevalence of CTS is higher in women than men. CTS is more frequently encountered in the dominant hand, while in 8-50 % of the cases it is bilateral (Szabo et al, 1992).

The most frequent morphological change encountered in CTS is diffuse or local swelling and flattening of the nerve which occurs while it traverses the carpal tunnel. Phalen has reported bullous median nerve swelling (pseudoneuroma) in 45, and flattening of the median nerve under the flexor retinaculum in 151, of the 212 patients examined in his study (Buchberger et al, 1992).

Clinical history, physical examination, and electrodiagnostic studies usually suffice for the diagnosis of CTS. The most prominent symptoms are paresthesia and pain (Ertekin, 2006). It has been reported that Tinel test positivity was between 8-100 % in CTS patients. Phalen test results have been reported to be positive in 10-88 % of CTS patients (Posch et al, 1976).

The diagnosis of CTS is mainly clinical; but the standard modality of diagnosis is electrodiagnostic studies which comprise neural conducting tests and electromyography (EMG). In 1993, the American Association of Electrodiagnostic Medicine declared that the diagnosis of CTS could be made appropriately only in the presence of an excellent electrodiagnostic work-up (Jablecki et al, 1993).

There are hard times for the diagnosis of CTS when the clinical findings are in favor of, but the electrodiagnostic results are at odds with, CTS. In such situations, it is debatable to reach a decision if or not to go for surgery. This conflict has given pace to the studies which aim to image and evaluate the carpal tunnel by means of advanced imaging modalities such as MRI. In such patients, radiologic modalities possess a strong complementing function (Browning, 2004). Initial data concerning the use of MRI for the evaluation and diagnosis of CTS go back to the mid 1980s (Weiss et al, 1986).

Various MRI findings have been comparitively evaluated in the process of CTS. MRI parameters utilized up to now in order to evaluate CTS may be listed as follows: signal intensity of the median nerve and its contrast enhancement, median nerve diameter, bowing of the flexor retinaculum, median nerve flattening, carpal tunnel diameter, peritendinous and synovial pathological conditions, probable anatomical variations, and other pathological situations.

The recurrence rate of CTS following surgery has been reported to be 1-25 % (Steyers, 2002). The most frequent clinical etiological factors which contribute to the development of recurrence of CTS may be listed as follows: incomplete resection of the flexor retinaculum (1-11 %), fibrous proliferation or scarring (0.5-1 %,) inflammatory flexor tenosynovitis (0.1-0.7 %), reformation of the flexor retinaculum, and entrapment of the sensory palmar branch of the median nerve (Steyers, 2002; Uchiyama et al, 2005). The value of MRI in all of these evaluations is of utmost importance.

Middleton et al have investigated the anatomic and pathologic properties of the carpal tunnel in healthy individuals and patients with CTS, and have declared that MRI has a supremacy among all imaging modalities in the imaging of the carpal tunnel, due to its very high contrast resolution (Middleton et al, 1987).

The axial T1 and T2-weighted sequences are the mostly preferred ones in the imaging of the carpal tunnel and its ingredients. The T1-weighted sequence helps to determine the diameter and the swelling of the median nerve, while T2-weighted imaging demonstrates a very high efficiency in detecting the edema in the median nerve tract and its neighboring territories in the carpal tunnel. The flexor retinaculum may be visualized in both sequences (Bonel et al, 2001).

The nerve normally appears isointense in T2-weighted images. The signal intensity of the nerve increases when the nerve is damaged or degenerated. An increase in the diameter of the nerve points to more water content and degeneration of the nerve (Uchiyama et al, 2005).

One study pointed out that patients who were clinically diagnosed with CTS but whose electrodiagnostic results were negative demonstrated the following MR signal alterations characteristic with CTS: signal increase in the median nerve tract on T2-weighted images (93 %), increase in palmar bowing at the transverse carpal ligament level (86 %), flattening of the median nerve (76 %), and median nerve enlargement at the os pisiformis level (70 %) (Bagatur et al, 2002).

Buchberger et al examined 20 wrists of a group of 18 CTS patients with US and MRI and detected the following findings: swelling of the median nerve at the proximal site of the carpal tunnel in 16 (80 %) wrists, flattening of the median nerve at its distal aspect in 13 (65 %) wrists, and increase in palmar bowing of the flexor retinaculum in 9 (45 %) wrists (Buchberger et al, 1991).

In our study, 86 cases who had been diagnosed with CTS according to their clinical and electrodiagnostic results were examined by a 0.2 T open MR scanner. At the end of the examinations, the MRI findings of 80 cases were evaluated in favor of CTS. The following findings were detected in these patients: signal increase in the median nerve tract in 80 (93 %) cases, increase in palmar bowing at the flexor retinaculum in 75 (87.2 %) cases, and flattening of the median nerve in 42 (48.8 %) cases. When these MRI findings were compared with the gold standard electrodiagnostic test results, the sensitivity of MR was found to be 93.02 % (85.42-97.38 %), and its positive predictive value (PPV) as 100 % (95.45-10.00). Our results show congruence with the literature.

Although they cannot always produce the same high-level resolution and signal-to-noise ratio (SNR) as the high-field closed-bore magnets, low-field open scanners, too, may produce satisfying MR images, especially from the soft tissue compartments. Our 0.2 T open scanner proved to be very effective in creating such high-quality images from the wrist region, which made it possible to obtain detailed information about the median nerve itself and its nearby vicinities.

As a closure note, we conclude that MRI, and specifically the low-field open MRI we utilized in this study, is satisfyingly effective in creating good imaging quality in the demonstration of the median nerve and the neighboring soft tissue compartments around. We also conclude that MRI is a very effective modality in the diagnosis of CTS, and it should be the first modality of choice for the diagnosis, after the completion of clinical examinations and diagnosis. We think that EMG should be reserved as a secondary diagnostic tool when MRI findings are negative or suspicious. We also think that detailed anatomic data supplied by MRI is of utmost importance for the reliability of both the surgical intervention itself and postoperative follow-up (Fig. 5.1).

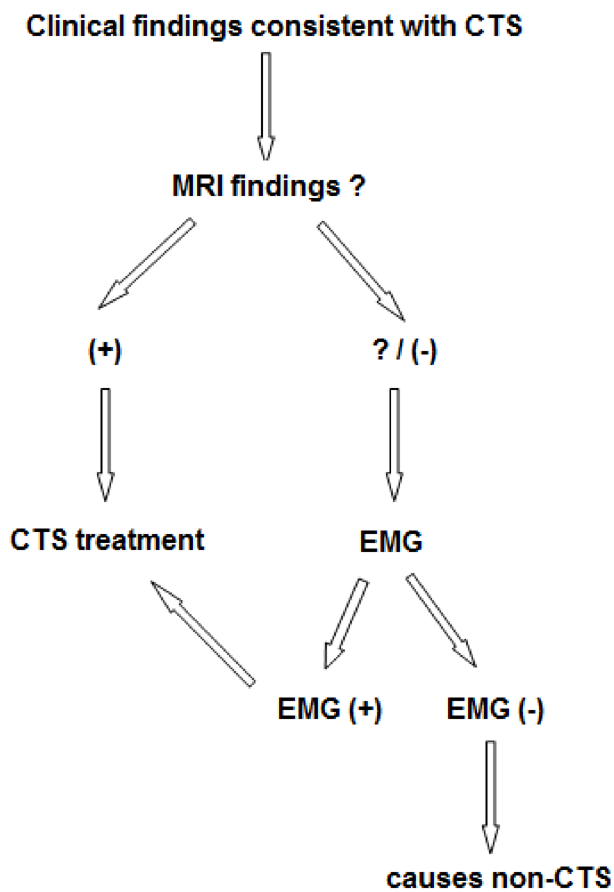

Figure 13. The algorithm we recommend, based on the results of our study, for patients who are considered to have CTS according to their clinical examination findings.

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