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Research Article

Diabetic Neuropathy Improves After Laparoscopic Diverted Sleeve Gastrectomy with Ileal Interposition: A Single Arm Electrophysiological Follow-Up Study

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Abstract

Objectives: The aim of the present study was to analyze the effect of laparoscopic diverted sleeve gastrectomy with ileal transposition (DSIT) surgery on diabetic neuropathy (DN) in patients with type 2 diabetes mellitus (T2DM).

Methods: This cross sectional, non-blinded, prospective, pilot study included 55 diabetic non-responders, who fail to achieve adequate glycemic control despite appropriate medical treatment. Electrophysiological tests including motor and sensory nerve conduction studies (NCS), sympathetic skin response (SSR) and R-R interval analysis of patients scheduled for metabolic surgical treatments were performed pre- and postoperatively. The differences in metabolic and electrophysiological parameters were also analyzed.

Results: Preoperative NCS evaluation revealed presence of polyneuropathy in 27 (49%) individuals; however, postoperative NCS values showed decreased distal conduction time in 61%, increased response amplitudes in 40% and increased conduction velocity in 57% of patients for motor nerves. As for sensory nerves, decreased distal conduction time was found in 55% and increased response amplitudes were detected in 57% of patients. In addition, significant improvements were observed in the of SSR and R-R interval analysis postoperatively.

Conclusion: Beyond the improvements in metabolic parameters and BMI in our diabetic patients who underwent DSIT, we also observed improved NCS results.

Keywords: Bariatric surgery, diabetic neuropathies, electrophysiological processes, neural conduction

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Globally, type 2 diabetes mellitus (T2DM) has become one of the most important chronic public health problems as an increasing cause of disability, chiefly through cardiovascular disease.[1] Based on World Health Organization data, the number of diabetic people worldwide is expected to increase from 171 million in 2000 to at least 366 million by 2030. In Turkey, the prevalence of T2DM among adults was 13.7% in 2010 according to TURDEP-II study.[2]

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Data from studies constantly signify that diabetic patients are more prone to develop micro- and macrovascular complications.[3, 4] Even earlier stages of diabetes, many patients show metabolic pathologies and, as shown by the United Kingdom Prospective Diabetes Study (UKPDS), at the time of T2DM diagnosis, about 50% of patients had considerable macro- or microvascular abnormalities.[5]

Chronic complications which are the main outcomes of T2DM progression may impair patients' quality of life (QoL), impose heavy burdens on healthcare systems, and increase diabetic mortality.[6–8] After adjusting for age, the death rate of patients with T2DM is nearly twofold as high as that of non-diabetic counterparts.[9] Permanent disability caused by late complications is a frequent result of uncontrolled diabetes.[10]

Neuropathy is one of the most common forms of diabetic end organ damage and distal symmetrical polyneuropathies (DSP) constitute the most frequent type of neuropathy. TURNEP study, a hospital based survey performed in 2003, demonstrated that clinical signs of DSP occurred in 40.4% of diabetics and this ratio increased to 62.2% when clinical signs were combined with EMG findings.[11] In the same study, the prevalence of neuropathic pain was 14%. The pathogenesis of diabetic neuropathy (DN) is complex and involves multiple pathways. Thus, early detection and accurate diagnosis before the onset of symptoms are of paramount importance in delaying or reversing the progression of this complication. The most important denominator in the progression of DN is glycemic regulation since appropriate glycemic control leads to positive changes in the course of neuropathy.[11, 12]

In the present study, we analyzed the incidence of DN via electrophysiological testing of patients scheduled for metabolic surgical treatments. At a mean of 8 months after surgery, the electrophysiological tests were repeated and differences in electrophysiological parameters were evaluated to investigate the effects of the operation on measures of neuropathy.

Methods

Study Design

The Clinical Research Ethics Committee of the German Hospital Istanbul, Metabolic Surgery Clinic approved the study (14/10/2011, no. 14/2011). All patients gave written informed consent prior to enrollment in the study.

All procedures were performed in accordance with the guidelines of the Center of Excellence in Bariatric and Metabolic Surgery, obtained from the Surgical Review Corporation of the hospital where the operations were performed. A.C. is a Surgeon of Excellence in Bariatric and Metabolic Surgery, certified by the same institution. This certification process requires establishment of a dedicated team with a fully integrated digital database where all preoperative and postoperative data were recorded and analyzed. The demographics and disease specific data of individuals were recorded and analyzed in accordance with these guidelines. Each patient was given an information form explaining the procedure and informed consent form to sign, in line with the principles and standards of good clinical practice, which includes assurance of personal integrity and welfare of patients in accordance with the Declaration of Helsinki.

This cross sectional, non-blinded pilot study included 55 severely diabetic non-responders, who fail to achieve adequate glycemic control despite appropriate medical treatment. Electrophysiological testing of patients scheduled for metabolic surgical treatments were performed preoperatively and at postoperative 8 months.

The inclusion criteria were: (a) >3-year history of T2DM, diagnosed in accordance with international standards (WHO 1999), i.e., fasting plasma glucose (FPG) concentration ≥7.0 mmol/L and/or 2-h postprandial plasma glucose (PPG) or random plasma glucose concentration ≥11.1 mmol/L with diabetic symptoms;[13] (b) repeated HbA1c values >7.5 while under regular anti-diabetic drug treatment for at least 1 year; and (c) stable weight profile for the last 3 months, defined as no significant change (>3%) in weight within the past 3 months; (d) ≥18 years old and Body Mass Index (BMI) >25 kg/m^2; (e) no other cause of polyneuropathy except for diabetes, no drug or substance abuse that may be associated with polyneuropathy (f) being an eligible candidate for Metabolic Surgery (g) ability to provide written informed consent to participate in the study. Pregnancy, history of major gastrointestinal surgery, severe eating problems, use of medications for eating disorders and entrapment neuropathy were exclusion criteria. All patients were preoperatively evaluated by the same team by means of a detailed complication screening program conducted over 3 days, including electrophysiological tests. All electrophysiological tests were performed by the same team (T.A., M.E.) and all operations were performed by the same surgeon (A.C.).

Surgical Technique

Laparoscopic diverted-sleeve gastrectomy with ileal transposition (DSIT) has been described previously.[14] Briefly, the technique involves a sleeve gastrectomy or fundectomy (depending on BMI) and transection of the gastroduodenal route 2 cm distal to the pylorus. The stomach is then transferred to the lower abdomen via a transverse mesocolic opening and a 170-cm length of the ileum is prepared, with special attention to the preservation of the last 30 cm.

The ileal segment is interposed between the stomach and jejunum, leading to an initial exposure of the nutrients with the ileal mucosa that causes increases in distal ileal neuropeptides, such as GLP-1 and peptide YY.[13]

Preoperative Procedures

All patients were evaluated preoperatively (1 month before surgery) with an extended 3 day routine complication screening program. This evaluation included routine blood analysis, thyroid functions, routine Doppler ultrasound examination of the carotid-vertebral arteries and lower extremities, echocardiography (ECHO), and computed tomography angiography (CT angio) of the coronary vessels. All procedures were recorded and analyzed in detail, including operational time, perioperative, and postoperative adverse events. Preoperatively 6 patients (10.9%) had iron deficiency anemia, 18 (32.7%) had Vitamin D deficiency, and 29 (52.7%) were receiving Vitamin B12 supplementation. These subjects were operated after the correction of underlying deficiencies. All patients received routine multivitamin supplements for at least 6 months after surgery. At postoperative month 12; 4 patients (7.2%) had iron deficiency anemia 7 (12.7%) had Vitamin D deficiency and 5 (9.09%) required Vitamin B12 supplements.

Electrophysiological investigations

All patients were examined by two channels Neuro EMG Micro model (Neurosoft, Ivanovo, Russia) electroneuromyography (ENMG) instrument. Examinations were performed with similar recording and stimulating electrodes under ideal room conditions and temperature.

Nerve conduction studies (NCSs): Sensory nerve action potential (SNAP) amplitudes and distal latencies were recorded in the left sural and bilateral median and ulnar sensory nerves. Distal motor latency (DML), compound muscle action potential (CMAP) amplitudes, and motor conduction velocities were recorded in the bilateral median and ulnar nerves as well as left tibial and peroneal motor nerves. Sensory and motor NCSs were carried out using standard procedures.[15]

Data obtained in the NCSs were assessed according to normal reference limits. NCS parameters were evaluated as pathological if median nerve distal sensory latency was 3.5 ms or more, sensory amplitude 20 uV or smaller, ulnar nerve distal sensory latency 3.1 ms or more, sensory amplitude 18 uV or smaller, sural nerve distal latency 3.8 ms or more, amplitude 10 uV or smaller, median nerve distal motor latency is 4.2 ms or more, amplitude 4 mV or smaller, conduction velocity 50 m/s or smaller, ulnar nerve motor distal latency 3.4 ms or more, amplitude 4 mV or smaller, conduction velocity 50 m/s or smaller, tibial nerve motor latency 6 ms or more, amplitude 3 mV or smaller, conduction velocity 40 m/s or smaller, peroneal nerve motor distal latency 5.5 ms or more, amplitude 2.5 mV or smaller and conduction velocity 40 m/s or smaller.[16]

Nerve conduction studies were performed twice as preoperatively and postoperatively after a mean duration of 8 months. Diagnosis of polyneuropathy was established regarding the 11 different nerves as ulnar (sensory and/or motor), median (sensory and/or motor), sural (sensory), tibial and peroneal (motor) nerves, if different nerves which were more than one in the right or left side were pathologic.[15] Additionally, differences between the nerve conduction parameters tested in two different NCSs in the preoperative and postoperative periods were compared.

Autonomic tests: For ideal autonomic test praxis, a comfortable and quite setting was provided for the patients. Factors which may affect the test results were avoided such as drug use except for antidiabetics or critical drugs. Heavy exercise was omitted at least one day before the tests, use of caffeine, alcohol, or smoking was ceased at least four hours before tests. The room temperature was set as 22–23°C and body temperature was adjusted to be higher than 34°C.

Sympathetic skin response test: Skin was cleaned using an alcohol-based solution on a cotton-wool ball. The surface Silver-Silver chloride (Ag-AgCl) electrodes were attached by a paste on the palm and on the sole of the foot which were both active. The reference electrodes were placed at the dorsum of the hand and foot. The ground electrode was placed 4-5 cm away from the reference electrode on the same extremity. Stimulation was carried out from the medial nerve at the opposite extremity wrist level in the upper extremities and from the tibial nerve at the opposite extremity ankle level in the lower extremities. Stimulation was administered at an interval of at least 1 minute between two stimuli and at irregular (randomized) intervals to avoid the loss of response due to habituation phenomenon.

The stimulation period was determined as 0.1 milliseconds (ms) and stimulation intensity was determined as 12 milliamper (mA) in the upper extremities and 16 mA in the lower extremities. Frequency filter adjustments were set as 0.1- 1000 Hz, sensitivity as 0.5-2 microvolt (mV)/division (div), scanning time as 1 second/division (s/div). The SSR latencies were measured from the starting point of first deflection by using a cursor and calculated in milliseconds. The absence of response was assessed as a criterion of pathology.[17–19]

R-R interval variability: The test was applied when the patient was comfortable, eyes shut and awake, lying on the examination couch in the supine position in a quiet room.

After cleaning the skin Ag-AgCl surface, recording electrodes were attached on 4th or 5th intercostal spaces by a conductive paste. The ground electrode was placed on the sternum region. No external stimulus was carried out during recording that were done during rest. Filter adjustments were set as 1-20 Hz, sensitivity as 100-200 mV/div, scanning time as 0.5 second. R-R interval variability (RRV%) was calculated by subtracting the shortest R-R interval from the longest R-R interval, multiplying it by 100 and then dividing the result to the mean R-R interval. [(RR maximum-RR minimum) x100/ mean RR]. The results which were obtained during the pre- and postoperative periods were compared.[19]

Statistical Analysis

The SPSS (ver. 15.0) software was used for statistical analyses. Descriptive tests and χ^2 tests were used as appropriate.

Results

This series consisted of 30 males (54.5%) and 25 females (45.5%), with a mean age of 52.45±9.59 years. Nerve conduction studies were repeated 8.4±2.3 months after surgery. A total of 19 patients (34.5%) had previous cardiovascular events. Of those, 11 (57%) had coronary stents. Co-morbidities included hypertension in 35 (63.6%), hypercholesterolemia in 33 (60%), and hypertriglyceridemia in 26 patients (47.2%). Eleven patients (20%) had retinopathy and 9 (16%) had diabetic nephropathy. Thirty-two patients underwent synchronous cholecystectomy and one patient underwent Meckel's diverticulectomy during surgery. None of these cases developed postoperative complications. Two complications consisting of bleeding and urinary tract infection were noted and both cases resolved completely with conservative treatment. No mortality was encountered in this series and all cases were followed up for the first year at 1-3-6-9-12 month intervals.

Mean HbA1C decreased from 9.6±2 to 6.8±1 at month 6 and to 6.6±1 at month 12 evaluations (p<0.001). Mean preoperative body weight of the patients was found as 94.0±14.7 kg, while this value was 71.7±13.3 kg at postoperative 8th month. The mean difference in body weight was calculated as -22.3±9.2 kg. Mean preoperative and postoperative 8th month BMI values were 34.0±5.1 kg/m^2 and 26.1±3.5 kg/m^2; respectively (p<0.001). The mean difference in BMI was -7.9±2.5.

Preoperatively, of 52 cases, 27.3% had no pathology in any of examined 5 nerves. However, 23.6% of patients had pathology in one nerve, 7.3% in 2 nerves, 5.5% in 3 nerves, 5.5% in 4 nerves and 30.9% in 5 nerves (all examined nerves). Thus, preoperative NCS evaluation revealed presence of polyneuropathy (abnormality in more than one nerve out of 5 nerves) in 23 (49%) of 52 cases.

In total we detected pathological values of median nerve in 33 (60%), ulnar nerve in 26 (47.3%), sural nerve in 22 (40%), and of tibial and peroneal nerves in each 23 (41.8%) patients (Table 1).

Tables 2 and 3 demonstrate the alterations in NCS parameters after surgery. Repeated measurements of NCS after a mean period of 8 months, demonstrated improved nerve conduction parameters which included 9 (81.8%) of the tested 11 nerves (both sides median and ulnar sensory/motor, left sural, left tibial and peroneal motor) and 16 (57.1%) of the examined 28 parameters (for sensory nerves distal latency and amplitude, motor nerves distal latency, amplitude and conduction velocity). The mean values for each motor and sensory nerve parameters which improved, deteriorated or unchanged in the postoperative period are shown in Table 4 with a more detailed evaluation ("Improved" is defined as shortened distal latency, increased amplitudes and increased conduction velocity). According to these values, shortening in distal latency was observed in 61% of motor nerves. Also, 40% of patients showed increase in amplitudes and 57% of patients in conduction velocity. For sensory nerves, we observed shortening in distal latency in 55% and increase in amplitudes in 57% of patients.

Whereas the rates of pathological findings in the upper extremity SSR examination showed no significant differ-

Table 2. Improvement of NCS results in our series

Variable	Number of patients (%)
Motor amplitude	45 (81.8)
Motor conduction velocity	53 (96.4)
Motor latency	52 (94.5)
Sensory amplitude	46 (83.6)
Sensory latency	48 (87.3)

Table 1. The number and percentage of patients with preoperative nerve pathology (%)

Median nerve			Ulnar nerve			Sural nerve	Tibial nerve	Peroneal nerve
Sensory	Motor	Any	Sensory	Motor	Any	Sensory	Motor	Motor
30 (54.5)	28 (50.9)	33 (60.0)	20 (36.4)	21 (38.2)	26 (47.3)	22 (40.0)	23 (41.8)	23 (41.8)

ence between the preoperative and postoperative tests, the pathological findings in the lower extremity responses were found to be significantly decreased (p=0.002). When the upper and lower extremity SSR responses were evaluated together, significant decrease was determined in number of the pathological findings (p=0.002). The R-R interval values, an important marker for cardiovascular autonomic function and associated with increased risk of silent myocardial ischemia and mortality, in 4 patients which were evaluated as pathological in the preoperative tests remained between normal limits postoperatively (p<0.001) (Table 5).

Remarkably, the patients showing an improvement in response amplitudes were the same ones that present amelioration in conduction velocity and/or distal conduction time. The same circumstance was valid for the electrophysiological parameters tested.

In total, 25 patients (45.4%) had complete remission (CR: HbA1c<6%), and 10 (18.2%) had partial remission (HbA1c<6.5%). In total, 46 patients were off anti-diabetic medications and had HbA1c below 7%. Nine patients (16.36%) required oral antidiabetic medications. Mean BMI dropped from 34.0±5.1 kg/m^2 to 26.1±3.5 kg/m^2 and 36 patients (65.5%) returned in to a normal BMI (20-25 kg/m^2). About co-morbidities, 29 of 35 patients (82.8%) with hypertension, 27 of 30 patients (90%) with hypercholesterolemia, and 19 of 26 patients (73%) with hypertriglyceridemia had normal levels without additional treatment.

Table 3. Alterations in NCS components after surgery in our series

Parameter	Number of patients (%)
Any improvement in any parameter (amplitude, latency, CV)	55 (100.0)
Improvement in both motor amplitude and motor CV	44 (80.0)
Improvement in both motor amplitude and motor latency	43 (78.2)
Improvement in both sensory amplitude and sensory latency	41 (74.5)
Improvement in both motor amplitude and sensory amplitude	38 (69.1)
Improvement in both motor CV and motor latency and sensory latency	46 (83.6)
Improvement in both motor amplitude and sensoy amplitude and motor CV	37 (67.3)
Improvement in both motor and sensory amplitudes and motor and sensory latencies	35 (63.6)

CV: conduction velocity.

Table 4. Mean nerve conduction study values for the motor and sensory nerve parameters in the postoperative period

Improvement as percentage of examined nerves	Distal latency (decrease) (%)	Amplitude (increase) (%)	Conduction velocity (increase) (%)
Median motor	80	41	65
Median sensory	70	49	not measured
Ulnar motor	51	33	53
Ulnar sensory	46	54	not measured
Sural sensory	48	47	not measured
Tibial motor	58	49	58
Peroneal motor	51	38	47
All motor nerves	61	40	57
All sensory nerves	55	50	not measured

Table 5. The rates of the pathological findings in pre- and postoperative Sympathetic Skin Response and R-R interval tests

Pathology in patients	Preoperative (%)	Postoperative (%)	p
SSR hand	4 (7.3)	3 (5.5)	NS (0.074)
SSR foot	8 (14.5)	5 (9.1)	0.002
SSR hand or foot	8 (14.5)	5 (9.1)	0.002
R-R interval	4 (7.3)	0 (0.0)	full improvement
Autonomic test (SSR or R-R)	8 (14.5)	5 (9.1)	0.002

p: statistical significance by Pearson Chi-Square test with 95% confidence level; NS: not significant; SSR: Sympathetic Skin Response.

Discussion

Our results indicate that electrophysiological tests demonstrated marked improvements in a significant number of obese and poorly controlled diabetic patients after DSIT. Additionally, mean HbA1c, body weight and BMI were significantly decreased in comparison with the preoperative period.

Diabetic neuropathy (DN) involves components of the autonomic and somatic nervous systems and is a frequent complication of DM. Contributing factors are vascular insufficiency, defective neurotrophism, oxidative stress, persistent hyperglycemia, and autoimmune nerve damage.[20] Of affected individuals, 25% are symptomatic, 50% have symptoms identified by clinical inspection, and nearly 95% have objective signs during the assessment of nerve function.[21]

The diagnosis of DN should be established along with clinical signs and symptoms, laboratory and electrophysiological examination results. Several methods for the detection of peripheral DN including quantitative methods (e.g., NCSs), vibration sense testing, pinprick tests, thermal tests, and several scales are available.[11] The use of NCS measures in multicenter clinical trials is recommended.[22, 23] Diabetic neuropathy typically involves both small and large nerve fibers and electrophysiological evidence can be revealed with standard procedures.[24, 25] The NCS is the gold standard for polyneuropathies affecting large-diameter myelinated fibers.[26] Methods which do not depend on conduction, such as skin biopsy with quantification of intraepidermal nerve fibers or quantitative sensory testing are also important for the identification of affected patients.[27] Because early detection of sensory disorders and pain is not easy in practice, establishment of a specific diagnosis requires 86% sensitivity of vibration sensation testing, and 85% sensitivity of neurological examination, and 71% sensitivity of conduction velocity studies.[28] In the present study, preoperative NCS evaluation revealed presence of polyneuropathy in 27 individuals (49%). Repeated NCS, mean 8 months after surgery showed improved NCS values for nine of the tested 11 nerves (81.82%) and 16 of 28 parameters (57.14%). Additionally, pathological finding rate at postoperative lower extremity SSR tests showed significant reductions. The increase in R-R interval values in four patients before surgery returned to normal values in the postoperative evaluation. Postoperative measurements also showed improvement in motor, sensory and autonomic nerve fibers.

Treatment of DN should have several targets: tight glycemic control, specific underlying pathogenic mechanisms, symptoms and improvement in QoL, prevention of progression, and complications of neuropathy.[25, 29] The Diabetes Control and Complications Trial (DCCT) group revealed that evidence of neuropathy was decreased by 50% in patients taking insulin with the control of blood glucose and HbA1c.[30] In the UKPDS, improvement in vibration perception was found to be associated with blood glucose control.[30, 31] Steno trial, with the use of multifactorial interventions, revealed a decrease in the odds ratio to 0.32 for the autonomic neuropathy development.[32] EURODIAB Prospective Complications study showed that DN was associated with cardiovascular risk factors such as high BMI, high triglyceride level, hypertension, and smoking.[33] Thus, DN treatment should include reducing macrovascular risk factors (hyperglycemia, hypertension, and hyperlipidemia), with pharmacological therapy and/or lifestyle modifications (weight reduction, smoking and alcohol cessation, and a diet rich in omega-3 fatty acids.[32]

In the present study, the patients who faced difficulties in controlling diabetes and underwent DSIT achieved improved results in the nerve conduction studies at postoperative 8 months, suggesting further improvements on the vascular and metabolic physiopathology of diabetes. Our patients did not experience any kind of hypoglycemia, which may be related to neurological outcomes. Also, since DSIT is not related to severe malabsorption, we did not encounter mineral or vitamin deficiencies in the majority of our patients.[13]

After obesity surgery, 40-95% of patients with T2DM show early remission of hyperglycemia.[34] The extent to which other diabetes-associated comorbidities, such as DN, might be influenced by obesity surgery is not known. Rapid, intensive glycemic control is somewhat controversial because the DCCT revealed a seemingly paradoxical deterioration of microvascular complications, such as retinopathy and neuropathy, after rapid glucose lowering in patients with type 1 diabetes.[35, 36]

In a prospective cohort study, 20 patients with long-standing, insulin-dependent T2DM and BMIs of 25–35 kg/m^2 who were treated by Roux-en-Y gastric bypass showed significant improvements in peripheral DN, as quantified by the Neuropathy Symptom Score and the Neuropathy Deficit Score, 6 months after surgery. In the same study, symptomatic neuropathy was completely reversible in 67% of the patients.[34]

In another prospective case-control study of 54 obese patients with T2DM undergoing gastric bypass surgery, microvascular complications were assessed 6 months before and 12–18 months after the intervention. Peripheral neuropathy was assessed through NCSs and no clinically significant change was observed at 1 year in any NCS variable. The authors noted that the stability of neuropathy after 1 year was reassuring because effects on retinal and neuronal function may manifest more than 1 year after bariatric surgery.[37]

There is a significant gap in the literature for the effects of surgery on DN. This study aimed to provide further evidence of the impact of DSIT, a rarely performed surgical procedure, on glycemic control and DN in obese patients with poorly controlled diabetes and peripheral neuropathy that is unresponsive to medical treatment.

Cross-sectional design, relatively small sample size and lack of data for long-term follow-up after surgery constitute major limitations of the present study.

Conclusion

In conclusion, we observed improvement in NCS results beyond the improvements in metabolic parameters and BMI in our diabetic patients who underwent DSIT. Improvement in NCS variables may be an indicator of more effective glycemic control.

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The English in this document has been checked by at least two professional editors, both native speakers of English. For a certificate, please see: http://www.textcheck.com/certificate/J1SGM6

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Disclosures

Ethics Committee Approval: The Clinical Research Ethics Committee of the German Hospital Istanbul, Metabolic Surgery Clinic approved the study (14/10/2011, no. 14/2011).

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References

1. Roglic G, Unwin N, Bennett PH, Mathers C, Tuomilehto J, Nag S, et al. The burden of mortality attributable to diabetes: realistic estimates for the year 2000. Diabetes Care 2005;28:2130–5.
2. Satman I, Omer B, Tutuncu Y, Kalaca S, Gedik S, Dinccag N, et al.; TURDEP-II Study Group. Twelve-year trends in the prevalence and risk factors of diabetes and prediabetes in Turkish adults. Eur J Epidemiol 2013;28:169–80.
3. Lee ET, Keen H, Bennett PH, Fuller JH, Lu M. Follow-up of the WHO Multinational Study of Vascular Disease in Diabetes: general description and morbidity. Diabetologia 2001;44 Suppl 2:S3–13.
4. Turner RC, Holman RR. Lessons from UK prospective diabetes study. Diabetes Res Clin Pract 1995;28 Suppl:S151–7.
5. LeRoith D, Fonseca V, Vinik A. Metabolic memory in diabetes-focus on insulin. Diabetes Metab Res Rev 2005;21:85–90.
6. Wang W1, Fu CW, Pan CY, Chen W, Zhan S, Luan R, et al. How do type 2 diabetes mellitus-related chronic complications impact direct medical cost in four major cities of urban China? Value Health 2009;12:923–9.
7. Liu ZL, Fu CW, Luan RS, Zhan SY, Chen WQ, Wang WB, et al. The impact of complication on quality of life among diabetic patients in urban China. Zhonghua Liu Xing Bing Xue Za Zhi 2008;29:1029–33.
8. Solli O, Stavem K, Kristiansen IS. Health-related quality of life in diabetes: The associations of complications with EQ-5D scores. Health Qual Life Outcomes 2010;8:18.
9. Geiss LS, Herman WH, Smith PJ. Mortality in non-insulin-dependent diabetes. Diabetes in America 1995;2:233–55.
10. Downs CA, Faulkner MS. Toxic stress, inflammation and symptomatology of chronic complications in diabetes. World J Diabetes 2015;6:554–65.
11. Erbas T, Ertas M, Yucel A, Keskinaslan A, Senocak M; TURNEP Study Group. Prevalence of peripheral neuropathy and painful peripheral neuropathy in Turkish diabetic patients. J Clin Neurophysiol 2011;28:51–5.
12. Schreiber AK, Nones CF, Reis RC, Chichorro JG, Cunha JM. Diabetic neuropathic pain: Physiopathology and treatment. World J Diabetes 2015;6:432–44.
13. DePaula AL, Macedo AL, Schraibman V, Mota BR, Vencio S. Hormonal evaluation following laparoscopic treatment of type 2 diabetes mellitus patients with BMI 20-34. Surg Endosc 2009;23:1724–32.
14. Celik A, Ugale S, Ofluoglu H, Asci M, Celik BO, Vural E, et al. Technical feasibility and safety profile of laparoscopic diverted sleeve gastrectomy with ileal transposition (DSIT). Obes Surg 2015;25:1184–90.
15. Preston DC, BE Shapiro. Electromyography and Neuromuscular Disorders E-Book: Clinical-Electrophysiologic Correlations (Expert Consult-Online). 2012: Elsevier Health Sciences.
16. Weiss LD, D Khanan, C Shtock. Tables of Normals. Easy EMG E-Book: A Guide to Performing Nerve Conduction Studies and Electromyography 2015:205.
17. Aramaki S, Kira Y, Hirasawa Y. A study of the normal values and habituation phenomenon of sympathetic skin response. Am J Phys Med Rehabil 1997;76:2–7.
18. Kucera P, Goldenberg Z, Kurca E. Sympathetic skin response: review of the method and its clinical use. Bratisl Lek Listy 2004;105:108–16.
19. Ravits JM. AAEM minimonograph #48: autonomic nervous system testing. Muscle Nerve 1997;20:919–37.
20. Vinik AI. Advances in diabetes for the millennium: new treatments for diabetic neuropathies. Medscape General Medicine 2004;6(3 Suppl).
21. Vinik A. Epidemiology of the complications of diabetes. Clini-

cal Science in Practice 1995.
22. Consensus statement: Report and recommendations of the San Antonio conference on diabetic neuropathy. American Diabetes Association American Academy of Neurology. Diabetes Care 1988;11:592–7.
23. Society PN. Diabetic polyneuropathy in controlled clinical trials: consensus report of the Peripheral Nerve Society. Annals of Neurology 1995;38:478–82.
24. Jensen TS, Hansson PT. Classification of neuropathic pain syndromes based on symptoms and signs, in Handbook of clinical neurology. Elsevier 2006;517–26.
25. Casellini C, Vinik A. Clinical manifestations and current treatment options for diabetic neuropathies. Endocrine Practice 2007;13:550–66.
26. de Wytt CN, Jackson RV, Hockings GI, Joyner JM, Strakosch CR. Polyneuropathy in Australian outpatients with type II diabetes mellitus. J Diabetes Complications 1999;13:74–8.
27. Sinnreich M, Taylor BV, Dyck PJB. Diabetic neuropathies: classification, clinical features, and pathophysiological basis. The neurologist 2005;11:63–79.
28. Mythili A, Kumar KD, Subrahmanyam KA, Venkateswarlu K, Butchi RG. A Comparative study of examination scores and quantitative sensory testing in diagnosis of diabetic polyneuropathy. Int J Diabetes Dev Ctries 2010;30:43–8.
29. Basić-Kes V, Zavoreo I, Rotim K, Bornstein N, Rundek T, Demarin V. Recommendations for diabetic polyneuropathy treatment. Acta Clin Croat 2011;50:289–302.
30. Control D, CTR Group. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. New England journal of medicine 1993;329:977–86.
31. Group UPDS. Tight blood pressure control and risk of macrovascular and microvascular complications in type 2 diabetes: UKPDS 38. BMJ: British Medical Journal 1998;317:703.
32. Gaede P, Vedel P, Larsen N, Jensen GV, Parving HH, Pedersen O. Multifactorial intervention and cardiovascular disease in patients with type 2 diabetes. N Engl J Med 2003;348:383–93.
33. Schram MT, Chaturvedi N, Schalkwijk C, Giorgino F, Ebeling P, Fuller JH, et al; EURODIAB Prospective Complications Study. Vascular risk factors and markers of endothelial function as determinants of inflammatory markers in type 1 diabetes: the EURODIAB Prospective Complications Study. Diabetes Care 2003;26:2165–73.
34. Müller-Stich BP, Fischer L, Kenngott HG, Gondan M, Senft J, Clemens G, et al. Gastric bypass leads to improvement of diabetic neuropathy independent of glucose normalization--results of a prospective cohort study (DiaSurg 1 study). Ann Surg 2013;258:760–5.
35. Leow MK, Wyckoff J. Under-recognised paradox of neuropathy from rapid glycaemic control. Postgrad Med J 2005;81:103–7.
36. The effect of intensive diabetes treatment on the progression of diabetic retinopathy in insulin-dependent diabetes mellitus. The Diabetes Control and Complications Trial. Arch Ophthalmol 1995;113:36–51.
37. Miras AD, Chuah LL, Khalil N, Nicotra A, Vusirikala A, Baqai N, et al. Type 2 diabetes mellitus and microvascular complications 1 year after Roux-en-Y gastric bypass: a case-control study. Diabetologia 2015;58:1443–7.