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Late Estimation of Sensibility Loss after Sural Nerve Autografting

Odległa ocena utraty czucia po pobraniu nerwu łydkowego

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Abstract

Background. Surgery requiring complementing peripheral nerve injury with a graft of another nerve, usually the sural nerve, has been performed at the Department of Traumatology and Hand Surgery, Silesian Piasts University of Medicine in Wrocław, since 1981. In the vast majority of cases the use of autografts of the sural nerve involved traumatic injuries of the brachial plexus or nerves of the upper and lower extremity. The area of sensibility loss, which decreases in the course of time thanks to other nerves taking over sensibility functions, is a consequence of sural nerve removal. On the basis of examinations, the authors assessed the degree of sensibility restoration in the sural nerve's innervation area in the extremity.

Objectives. Learning about the mechanisms of peripheral compensation of sensibility through quantitative and qualitative assessment of sensibility restoration in the innervation area of the sural nerve lost as a result of its removal in the reconstruction of brachial plexus and peripheral nerves.

Material and Methods. Fifty-two patients were examined in selected age groups operated on at the department because of traumatic injuries to peripheral nerves. Examination of two-point, soft, and vibration sensibility were performed. Additionally, the patients were tested for subjective assessment of sensibility restoration in the area of innervation by the sural nerve.

Results. On the basis of the performed quantitative examination and patients' subjective estimation of sensibility restoration, statistically significant correlations between sensibility restoration in the examined area and the time from surgery to the examination, patient age, or the length of the sural nerve graft were not observed. Much quicker sensibility restoration was observed in the areas of the 2nd and 4th innervation by the sural nerve, i.e. the skin of the heel from the medial side and of the fifth toe.

Conclusions. In assessing sensibility restoration after taking sural nerve grafts for the reconstruction of nerves (peripheral and of the brachial plexus), examination of soft sensibility with the help of Semmes-Weinstein filaments, two-point sensibility, and vibration sensibility play an essential role. The results of the above examinations showed very good and good results of sensibility restoration in 75% patients, while only 2% had unsatisfactory results (*Adv Clin Exp Med* 2007, 16, 2, 229–237).

Key words: sural nerve, microsurgical reconstruction of nerves (peripheral and of brachial plexus), soft sensibility, vibration sensibility.

Streszczenie

Wprowadzenie. W Klinice Chirurgii Urazowej i Chirurgii Ręki Akademii Medycznej we Wrocławiu od 1981 roku wykonuje się operacje wymagające uzupełnienia ubytku nerwu obwodowego wszczepem autogenicznego nerwu, którym rutynowo był nerw łydkowy. W większości przypadków zastosowanie autogenicznych wszczepów nerwu łydkowego dotyczyło urazowych uszkodzeń splotu ramiennego, urazowych uszkodzeń nerwów kończyny górnej i dolnej. Konsekwencją pobrania nerwu łydkowego jest występowanie obszaru utraty czucia, który w miarę upływu czasu zmniejsza się dzięki przejmowaniu funkcji czuciowych przez inne nerwy. Autorzy pracy na podstawie przeprowadzonych badań określili stopień powrotu czucia w obszarze unerwienia kończyny przez nerw łydkowy.

Cel pracy. Poznanie mechanizmów obwodowej kompensacji czucia przez ilościową i jakościową ocenę powrotu czucia, w okolicy unerwienia przez nerw łydkowy, utraconego w wyniku jego pobrania, w zabiegach rekonstrukcyjnych splotu ramiennego oraz nerwów obwodowych.

Materiał i metody. Badaniu poddano 52 pacjentów w wybranych grupach wiekowych operowanych w Klinice Chirurgii Urazowej i Chirurgii Ręki AM we Wrocławiu z powodu urazowych uszkodzeń nerwów obwodowych. Przeprowadzono badanie czucia dwupunktowego, czucia delikatnego oraz czucia wibracji. Dodatkowo pacjentów poddano ocenie subiektywnej powrotu czucia w obszarze unerwienia przez nerw łydkowy.

Wyniki. Na podstawie przeprowadzonych badań ilościowych i subiektywnej oceny przez chorego powrotu czucia, nie wykazano statystycznie istotnego związku między czasem powrotu czucia w badanych obszarach a czasem od operacji do badania, wiekiem pacjentów lub długością wszczepu nerwu łydkowego. Zaobserwowano znacznie szybszy powrót czucia w obszarze 2. i 4. unerwienia przez nerw łydkowy, tj. skóry pięty od strony przyśrodkowej i palca V.

Wnioski. W ocenie powrotu czucia po pobraniu wszczepów nerwu łydkowego do zabiegów rekonstrukcyjnych nerwów (obwodowych oraz splotu ramiennego) istotną rolę odgrywają badania czucia delikatnego za pomocą filamentów Semmes-Weinsteina, czucia dwupunktowego oraz czucia wibracji. Zebrane przez autorów wyniki powyższych badań wykazały bardzo dobry i dobry wynik powrotu czucia u 75% pacjentów, podczas gdy wynik niezadowolający zaledwie u 2% (*Adv Clin Exp Med* 2007, 16, 2, 229–237).

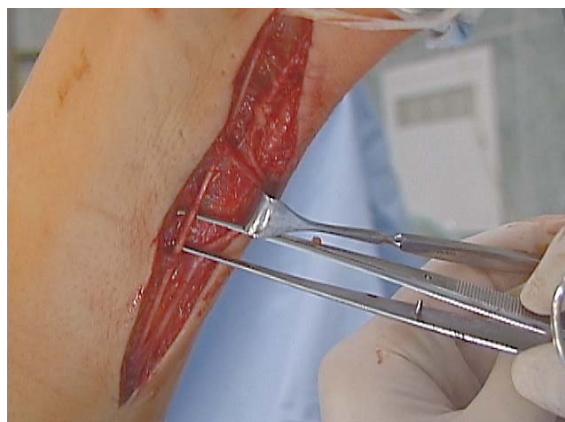
Słowa kluczowe: nerw łydkowy, mikrochirurgiczna rekonstrukcja nerwów (obwodowych i splotu ramiennego), czucie dotyku, czucie wibracji.

Reconstructive surgery requiring complementing peripheral nerve loss with a graft of an autogenic nerve, usually the sural nerve, has been performed at the Department of Traumatology and Hand Surgery, Silesian Piasts University of Medicine in Wrocław, since 1981. In the place innervated by a nerve there is consequently an area of sensibility loss. This area should decrease in the course of time thanks to surrounding nerves taking over sensibility functions. However, this process is not always favorable and there are sometimes ailments in the form of painful neuroma in the stump of the sural nerve or an area of loss of sensibility or, also, an area of hyperaesthesia.

The purpose of this study was to assess qualitative and quantitative sensibility restoration in the area innervated by the sural nerve lost as a result of its removal in a group of patients, performed on the basis of a qualitative examination of pressure sensibility with the Semmes-Weinstein Monofilaments aestesiometer examination of discrimination of two-point sensibility and vibration sensibility.

In the majority of cases (66%) the use of autogenic grafts of sural nerve involved the reconstruction of traumatic injuries to the brachial plexus or the upper extremity, and, to a lesser degree (15%), isolated injuries to other peripheral nerves. The sural nerve is the most frequently applied as an autogenic sensory nerve graft in the reconstruction of peripheral nerves and those of the brachial plexus because of its length, thickness, easy operational harvesting (Figs. 1, 2), and the slight decrease in sensibility in the area of the foot [1, 9, 11].

The sural nerve is a sensory nerve innervating the lateral ankle and the external edge of the foot. It begins as a ramification of the medial sural nerve in the popliteal fossa and passes down between the heads of gastrocnemius muscle, lying



Figs. 1 and 2. Stages of taking the sural nerve by cutting just behind the lateral ankle

Ryc. 1 i 2. Etapy pobrania nerwu łydkowego z cięcia tuż za kostką boczną

under deep fascia. After leaving the fascia at the medial level of the calf, it joins the lateral sural nerve, creating the sural nerve. The sural nerve runs along the lateral edge of the Achilles (calcaneal) tendon to the lateral ankle, winding around it, and runs to the foot as the lateral cutaneous dor-

sal nerve to the edge of the foot and the little toe. It gives off lateral calcaneal branches to the skin of the heel and medial calcaneal branches which pass through the retinaculum of the flexors to the skin of the heel and the back part of the foot (Fig. 3). It consists, as authors have found, in the majority of cases (40.2–83.7%) of medial and lateral sural nerve and in rarer cases (0–16%) of lateral sural nerve [2, 5, 6, 12].

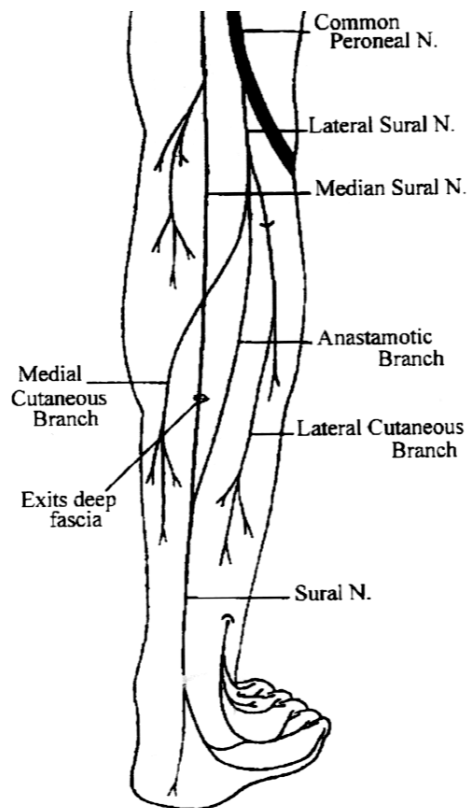


Fig. 3. Anatomy of the sural nerve: course of the sural nerve [2]

Ryc. 3. Anatomia nerwu łydkowego – przebieg nerwu łydkowego

Explanation (objaśnienie): common peroneal n. – nerw strzałkowy wspólny; lateral, median, sural nerve – nerw łydkowy boczny, przyśrodkowy; anastomotic branch – gałązka łącząca; medial, lateral cutaneous branch – przyśrodkowa, boczna gałązka skórna; sural n. – nerw łydkowy; exits deep fascia – wyjście nerwu łydkowego spod powięzi głębokiej

Material and Methods

Fifty-two patients (including 8 women) from 10 to 56 years old (mean: 29 years) operated on in the years 1982–2005 at the Clinic of Trauma and Hand Surgery, Silesian Piasts University of Medicine, were investigated because of traumatic injury to the brachial plexus and injuries to peripheral nerves. The basic statistical characteristic of the tested group of patients are gathered in Table 1 (p. XX) and presented in Figs. 4–7.

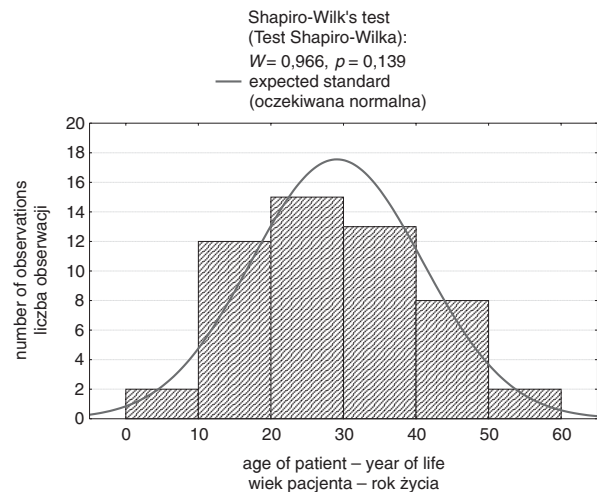


Fig. 4. Histogram of the patients' ages at admission to the clinic and the result of the normality test

Ryc. 4. Histogram wieku pacjentów w chwili przyjęcia do kliniki oraz wynik testu normalności

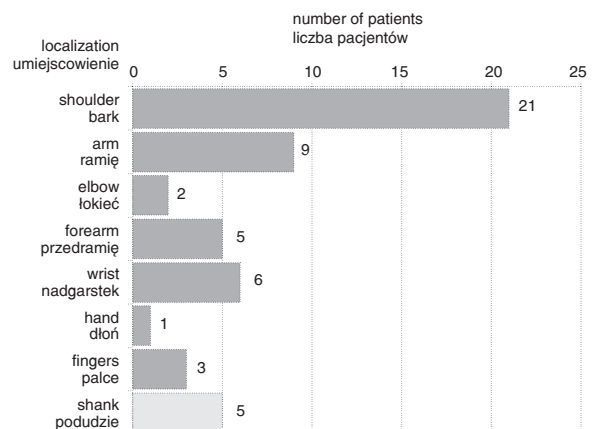


Fig. 5. Numbers of patients and injury location

Ryc. 5. Liczba pacjentów w zależności od umiejscowienia uszkodzenia

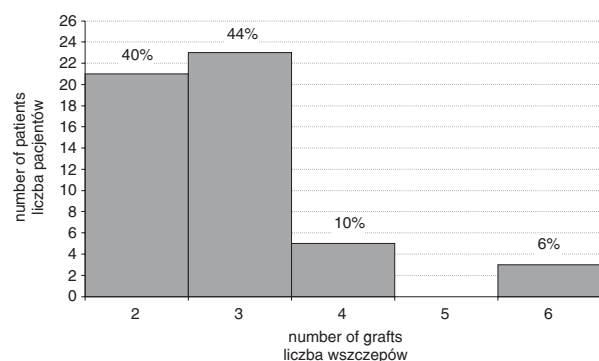


Fig. 6. Numbers of patients and grafts

Ryc. 6. Liczba pacjentów w zależności od liczby wszczepów

Pressure sensibility, performed with Semmes-Weinstein monofilaments, discrimination exami-

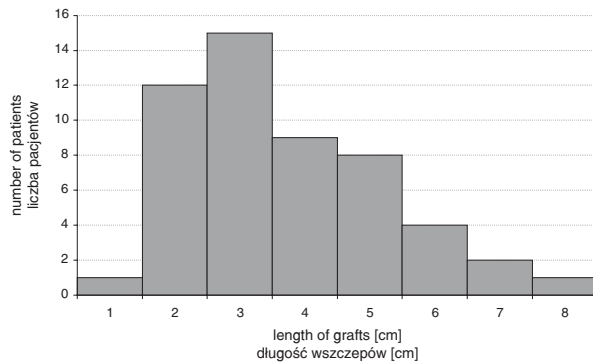


Fig. 7. Numbers of patients and graft lengths

Ryc. 7. Liczba pacjentów w zależności od długości wszczepów

nation of two-point sensibility, as well as vibration sensibility were assessed in the area innervated by the sural nerve after taking it for reconstruction of the brachial plexus and peripheral nerves. For the purpose of comparative analysis, the lower extremity from which the sural nerve was not taken was also examined.

To assess soft sensibility, a Semmes-Weinstein aesthesiometer (Roylan Semmes-Weinstein Mono-filaments, Smith and Nephew Royal) (Fig. 8) was used. The examination consisted of determining the threshold value pressure that the patient is able to feel in the area innervated by the sural nerve. In Table 2, the literal and numerical (logarithmic) des-

Table 1. Clinical characteristics of the 52 patients

Tabela 1. Charakterystyka kliniczna 52 pacjentów

	Females (Kobiety) <i>n</i> = 8 (15%)	Males (Mężczyźni) <i>n</i> = 44 (85%)	Total (Razem) <i>n</i> = 52 (100%)
Age – years (Wiek – lata): mean (średnia) \bar{x} standard deviation (odchyl. standard.) <i>SD</i> median (mediana) x_{Me} minimum (wartość minimalna) x_{mi} maximum (wartość maksymalna) x_{max}	24.4 17.5 14.5 10 51	30.0 10.5 29 13 56	29.1 11.8 28 10 56
Operated extremity and location of nerve reconstruction (Operowana kończyna i lokalizacja miejsca rekonstrukcji nerwu) <i>n</i> (%): upper (górna) shoulder – brachial plexus (bark – splot ramienny) arm (ramię) forearm (przedramię) elbow (łokieć) wrist (nadgarstek) hand (dłoń) fingers (palce) lower (dolna) shank (podudzie)	4 (50%) 1 (12%) 0 (0%) 0 (0%) 0 (0%) 2 (25%) 1 (12%) 0 (0%) 4 (50%) 4 (50%)	43 (98%) 20 (45%) 9 (20%) 5 (11%) 2 (5%) 4 (9%) 0 (0%) 3 (7%) 1 (2%) 1 (2%)	47 (90%) 21 (40%) 9 (2%) 5 (10%) 2 (4%) 6 (12%) 1 (2%) 3 (6%) 5 (10%) 5 (10%)
Number of grafts (Liczba wszczepów): mean (średnia) \bar{x} standard deviation (odch. standard.) <i>SD</i> median (mediana) x_{Me} minimum (wartość minimalna) x_{mi} maximum (wartość maksymalna) x_{max}	3.5 1.7 3 2 6	2.7 0.7 3 2 4	2.8 1.0 3 2 6
Graft length (Długość wszczepów) – cm: mean (średnia) \bar{x} standard deviation (odch. standard.) <i>SD</i> median (mediana) x_{Me} minimum (wartość minimalna) x_{mi} maximum (wartość maksymalna) x_{max}	5.2 1.3 5 4 7	3.6 1.8 3.2 1 8	3.9 1.8 3.8 1 8
Time from surgery to investigation – years (Czas od operacji do momentu badań – lata): mean (średnia) \bar{x} standard deviation (odch. standard.) <i>SD</i> median (mediana) x_{Me} minimum (wartość minimalna) x_{mi} maximum (wartość maksymalna) x_{max}	9.5 5.4 10.3 0.9 15.1	5.9 4.9 5.6 0.02 14.6	6.5 5.1 5.8 0.02 15.1

Table 2. Semmes-Weinstein monofilament designations and pressure forces corresponding with them**Tabela 2.** Oznaczenia monofilamentów Semmes-Weinsteina i odpowiadające im siły nacisku

	Literal designation (Oznaczenie literowe)	Numerical designation (Oznaczenie cyfrowe) $= \log_{10}(F(\text{mg}) \times 10)$	Pressure force F (in grams) Siła nacisku (w gramach)
Correct sensibility (Czucie prawidłowe)	A	1.65	0.0045
	B	2.36	0.023
	C	2.44	0.0275
	D	2.83	0.0677
Weakened sensibility (Czucie osłabione)	E	3.22	0.166
	F	3.61	0.4082
Protective sensibility (Czucie ochronne)	G	3.84	0.6958
	H	4.08	1.194
	I	4.17	1.494
	J	4.31	2.052
Lack of protective sensibility (Brak czucia ochronnego)	K	4.56	3.632
	L	4.74	5.5
	M	4.94	8.65
	N	5.07	11.7
	O	5.18	15
	P	5.46	29
	Q	5.88	75
	R	6.1	127
	S	6.45	281.5
	T	6.65	447

ignations and the corresponding pressure forces of the monofilaments are presented. Sensibility in the field innervated by the sural nerve was estimated according to the rules of Bell-Krostoski [3, 4]. After informing the patient, the test was begun, which consisted of softly and perpendicularly placing the particular monofilaments, from the thinnest to the thickest, and pressing them down onto the foot skin in the chosen fields until the hair bends and slowly sets back. The smallest pressure felt by the patient was noted in the logarithmic form.

The examination of statistical discrimination of two-point sensibility was performed using a sensibility discriminator of Mackinnon-Dellon (Disc-Criminator™) [8] (Fig. 8). Putting one- or two-point impulse to the skin of the foot in the chosen fields of innervation by the sural nerve, the smallest distance between the pins, from 2 to 15 mm, then from 20 and 25 mm, was noted [10].

Assessment of vibration sensibility was defined according to the rules given by Dellon [7] with the help of tuning forks with frequencies of 32 and 256 Hz which were put onto the examined innervation fields of the foot of the extremity from which the sural nerve was taken and the opposite, healthy extremity (Fig. 9). The achieved results were recorded.

Results

The results of the qualitative assessment of soft and two-point sensibility as well as those of

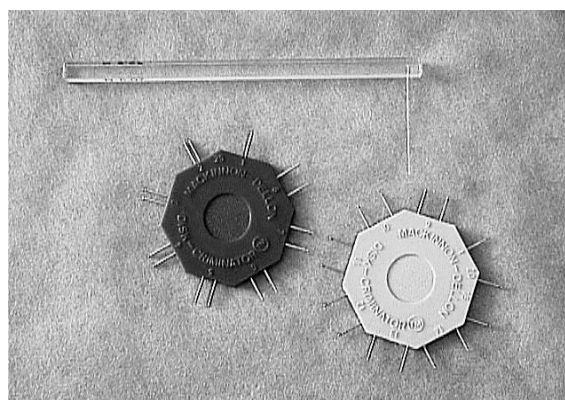


Fig. 8. Above: Semmes-Weinstein Monofilament, below: Mackinnon-Dellon sensibility discriminator

Ryc. 8. U góry ryciny Monofilament Semmes-Weinstein, poniżej dyskryminator czucia Mackinnon-Dellon

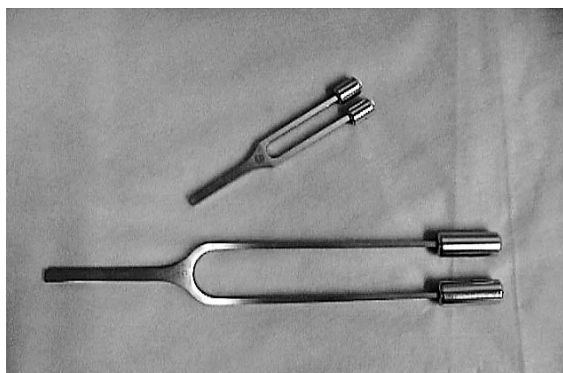


Fig. 9. Tuning forks with frequencies of 32 and 256 Hz

Ryc. 9. Kamertony o częstotliwości 32 i 256 Hz

quantitative examinations (subjective sensibility of patients) are presented in Tables 3–6 and Figs. 10–15.

Discussion

In this study, the degree of sensibility restoration was assessed in the innervation area of an

extremity after removal of the sural nerve for reconstructive procedures of the brachial plexus and peripheral nerves. The aim of this study was to learn about the mechanisms of peripheral compensation of sensibility in reconstructive procedures and to use the study results in clinical practice with regard to autografts of the sural nerve. Assessment of sural nerve function after its removal to make an autogenic graft was of particular interest.

Table 3. Qualitative examination of sensibility restoration in the area innervated by the sural nerve after its removal

Tabela 3. Ocena ilościowego powrotu czucia w okolicy unerwienia przez nerw łydkowy, po jego pobraniu

Examination place – area (Miejsce badania – obszar)	Extremity (Kończyna)	
	from which the nerve was taken N (%)	symmetrical N (%)
1. Skin at and below the lateral ankle in the direction of the heel, lateral side (Skóra – na wysokości i poniżej kostki bocznej w kierunku do pięty – strona boczna): correct sensibility (czucie prawidłowe (A–D)) weakened sensibility (czucie osłabione (E–F)) protective sensibility (czucie ochronne (G–J)) lack of protective sensibility (brak czucia ochronnego (K–T))	10 (20) 12 (23) 12 (23) 18 (34)	38 (74) 5 (9) 3 (6) 6 (11)
2. Heel skin, medial side (Skóra pięty – strona przyśrodkowa) correct sensibility (czucie prawidłowe (A–D)) weakened sensibility (czucie osłabione (E–F)) protective sensibility (czucie ochronne (G–J)) lack of protective sensibility (brak czucia ochronnego (K–T))	24 (46) 9 (17) 6 (11) 13 (26)	37 (71) 5 (9) 6 (11) 5 (9)
3. Skin of external surface of foot edge (Skóra zewnętrznej powierzchni brzegu stopy) correct sensibility (czucie prawidłowe (A–D)) weakened sensibility (czucie osłabione (E–F)) protective sensibility (czucie ochronne (G–J)) lack of protective sensibility (brak czucia ochronnego (K–T))	18 (34) 10 (20) 10 (20) 13 (26)	37 (71) 5 (9) 5 (9) 6 (11)
4. Skin of toe V (Skóra palca V) correct sensibility (czucie prawidłowe (A–D)) weakened sensibility (czucie osłabione (E–F)) protective sensibility (czucie ochronne (G–J)) lack of protective sensibility (brak czucia ochronnego (K–T))	22 (43) 13 (26) 10 (20) 6 (11)	42 (80) 3 (6) 3 (6) 4 (9)

Table 4. Results of the vibration sensibility examination at 32 Hz

Tabela 4. Wyniki badania czucia wibracji – 32 Hz

Vibration sensibility (Czucie wibracji)	Area 1 (Obszar 1)		Area 2 (Obszar 2)		Area 3 (Obszar 3)		Area 4 (Obszar 4)	
	o.	n.o.	o.	n.o.	o.	n.o.	o.	n.o.
Lack of sensibility (Brak czucia)	9 (17%)	2 (3%)	7 (14%)	0 (0%)	4 (9%)	3 (6%)	1 (3%)	0 (0%)
Weak positive (Słabe dodatnie)	25 (49%)	44 (85%)	36 (69%)	51 (97%)	36 (69%)	46 (88%)	42 (80%)	46 (88%)
Correct (Prawidłowe)	18 (34%)	6 (12%)	9 (17%)	1 (3%)	12 (22%)	3 (6%)	9 (17%)	6 (12%)

o. – oper. e. (k. nieoper.),

n.o. – non-oper. e. (k. nieoper.).

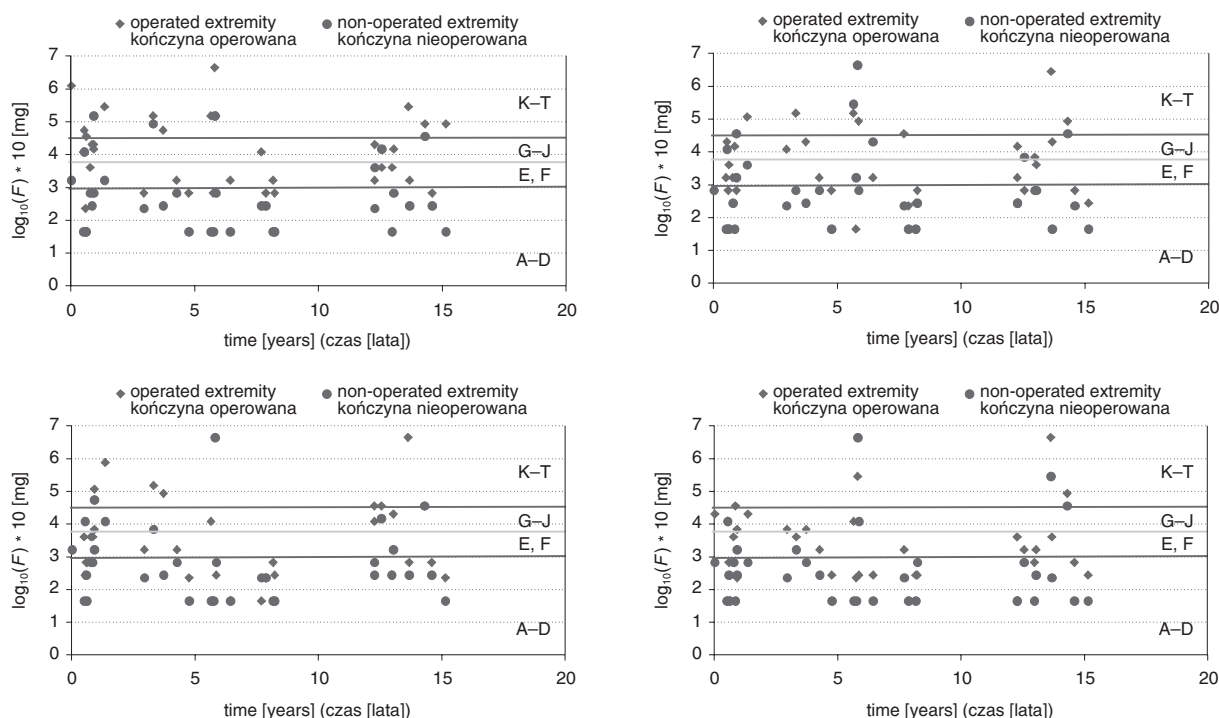
Table 5. Results of vibration sensibility examination at 256 Hz**Tabela 5.** Wyniki badania czucia wibracji – 256 Hz

Vibration sensibility (Czucie wibracji)	Area 1 (Obszar 1)		Area 2 (Obszar 2)		Area 3 (Obszar 3)		Area 4 (Obszar 4)	
	o.	n.o.	o.	n.o.	o.	n.o.	o.	n.o.
Lack of sensibility (Brak czucia)	10 (20%)	7 (14%)	7 (14%)	4 (9%)	12 (23%)	1 (3%)	7 (14%)	1 (3%)
Weak positive (Słabe dodatnie)	15 (29%)	9 (17%)	10 (20%)	6 (11%)	10 (20%)	10 (20%)	10 (20%)	9 (17%)
Correct (Prawidłowe)	27 (51%)	36 (69%)	35 (66%)	42 (80%)	30 (57%)	41 (77%)	35 (66%)	42 (80%)

o. – oper. e. (k. nieoper.); n.o. – non-oper. e. (k. nieoper.).

Table 6. Subjective assessment of the degree of sensibility restoration in the area innervated by the sural nerve**Tabela 6.** Ocena subiektywna stopnia powrotu czucia w obszarze unerwienia przez nerw łydkowy

Result (Wynik)	Examination place – area (Miejsce badania – obszar)			
	1 – below the lateral ankle and on the heel skin, lateral side (poniżej kostki bocznej i na skórze pięty – strona boczna) N (%)	2 – heel skin, medial side (skóra pięty – strona przyśrodkowa) N (%)	3 – skin of external surface of foot edge (skóra zewnętrznej powierzchni brzegu stopy) N (%)	4 – skin of toe V (skóra palca V) N (%)
Unsatisfactory (Niezadowolający)	6 (12)	0 (0)	6 (12)	1 (2)
Sufficient (Dostateczny)	21 (40)	3 (6)	10 (19)	6 (12)
Good (Dobry)	22 (42)	14 (27)	22 (42)	19 (37)
Very good (Bardzo dobry)	3 (6)	35 (67)	14 (27)	26 (50)

**Fig. 10.** Correlation diagram of sensibility dependence in areas A, B, C, and D innervated by the sural nerve at the time of its removal. Examination place – see Table 3**Ryc. 10.** Diagram korelacyjny zależności czucia w obszarze A, B, C, i D unerwienia przez nerw łydkowy od czasu pobrania. Miejsce badania – patrz tabela 3

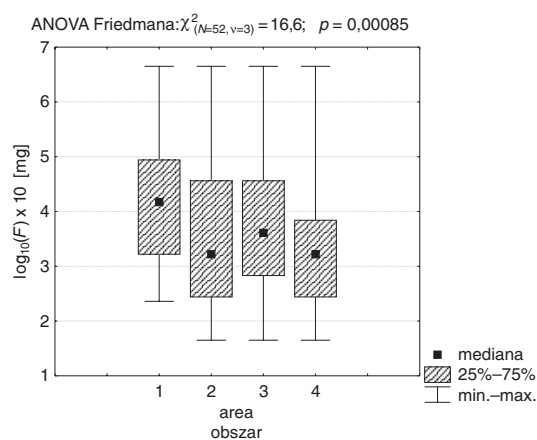


Fig. 11. Comparison of perceptible pressure force in the tested areas

Ryc. 11. Porównanie odczuwalnej siły nacisku w badanych obszarach

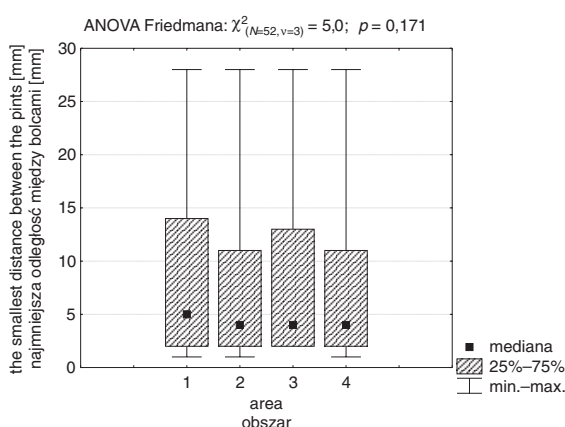
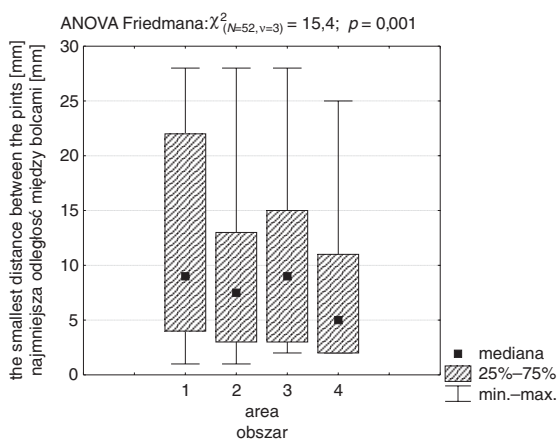
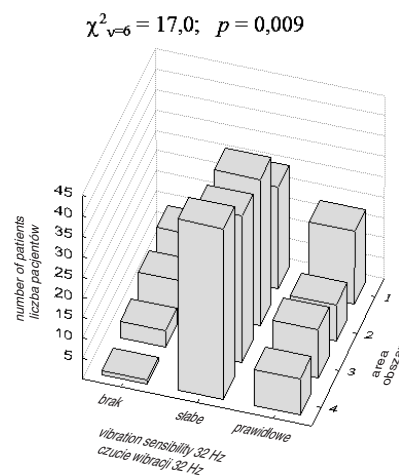


Fig. 12. Comparison of the smallest distance between discriminator pins felt in the examined areas of the operated extremity (above) and non-operated (below)

Ryc. 12. Porównanie najmniejszej odległości między bolcami dyskryminatora odczuwanej w badanych obszarach kończyny operowanej (powyżej) i nieoperowanej (poniżej)

In the cross-sectional examinations of soft sensibility, statistically significant correlations ($p > 0.05$) between sensibility restoration of the tested areas and the time which passed between surgery



$\chi^2_{v=6} = 5,0; p = 0,540$

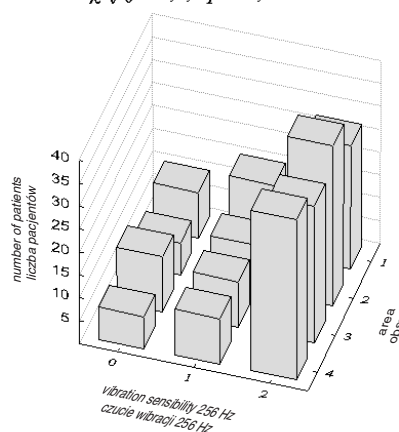


Fig. 13. Numbers of patients and vibration sensibility at 32 and 256 Hz in the examined areas of the foot and the results of the chi-squared test

Ryc. 13. Liczba pacjentów w zależności od czucia wibracji 32 i 256 Hz w badanych obszarach stopy oraz wyniki testu

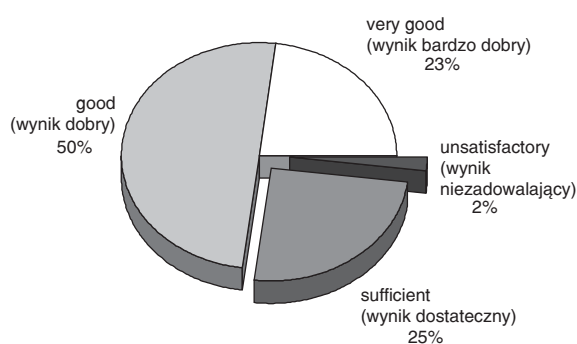


Fig. 14. Global subjective assessment of sensibility restoration – result

Ryc. 14. Globalna ocena subiektywna powrotu czucia – wynik

and examination as well as dependence on the age of patients, the number of grafts, and their lengths were not observed. Sensibility in the areas 2 and 4, i.e. in the area of the heel skin from the medial side and toe V, was essentially better than in the areas 1 and 3 (skin below the lateral ankle and the external

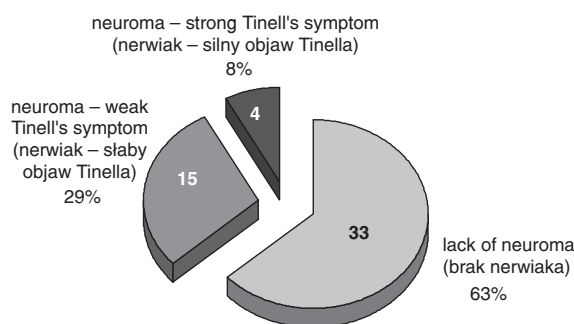


Fig. 15. Complications

Ryc. 15. Powikłania

surface of the foot edge), as illustrated by Fig. 11. Assessment of two-point sensibility showed significantly better ($p < 0.01$) restoration of that kind of sensibility in area 4 (skin of toe V) than in the remaining examined areas of the operated extremity. Differences were not observed in the non-operated extremity (Fig. 12).

Similar observations were in assessing vibration sensibility with a frequency of 32 Hz. It was observed that area 4 (skin of toe V) is essentially more sensitive to vibration at that frequency than the other tested areas. A significant difference in sensibility of the tested areas to vibration at a frequency of 256 Hz was not observed (Fig. 13). Subjective

assessment of the degree of sensibility restoration in the area innervated by the sural nerve showed a very good result of sensibility restoration in areas 2 and 4 (skin of the heel from the medial side and toe V) (Table 6). However, in the global subjective assessment of sensibility restoration reported by the tested patients, a very good result was achieved in 23% cases, good in 50%, satisfactory in 25% and unsatisfactory results in 2% (Fig. 14).

On the basis of this study, the authors observed that: 1) Use of the sural nerve is and will remain a routine procedure in the reconstruction of nerves requiring use of grafts for the proper length. The sural nerve is the most often used sensibility nerve because of the ease of its removal and the slight deficiencies in sensibility in the foot; 2) A large percentage (75% of cases) of sensibility restoration in the extremity after nerve removal as well as a lack of motor function defects and efficiency of gait were observed; any essential harms resulting to patients were thus not observed, and this is an essential practical aspect; 3) Examination of soft sensibility, two-point sensibility, and vibration sensibility plays an essential role in assessing sensibility restoration after iatrogenic injury of the sural nerve in patients treated with autogenic graft of the sural nerve, allowing learning about the mechanisms of the peripheral compensation of sensibility.

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