P79. Quantitative Analysis of Gait Patterns in Neurological Disorders

M. Hennerici, R. R. Diehl, U. Schneider, M. Konietzko, and J. Röther, Mannheim, Germany

Examination of gait disorders still is based on the visual inspection of a walking patient—thus, the pathological gait patterns such as spasticity, ataxia, or apraxia can only qualitatively be estimated. Modern video and computerized LED techniques enable more specific insights into single bases of locomotion; they are, however, insufficient for quantitative analysis or are adapted to the evaluation of small movement patterns only. We have introduced and validated recently in normal subjects a new computer-assisted dynamic version for the analysis of posture and gait. Data analysis contains a force-time diagram of a series of eight transducers set under the subject's soles in a pair of shoes (sample rate 50 Hz). Parameters such as step time, swing time, and stance time can be calculated as well as the resultant force vector from eight transducers. The gait cyclogram and the gait lines connect successive application points and display the monopedal and bipedal characteristics of gait. The analysis of 50 normal subjects and 150 patients with various forms of gait disturbances recently studied under various test conditions offers a straightforward quantitative differentiation of normal and abnormal gaits, as well as during treatment and spontaneous follow-up of the disease. Gait lines and cyclograms are illustrative representations of the gait characteristics. The individual data measurements are highly reproducible and the statistical analysis offers a reliable basis for the differentiation between normal and abnormal movements. Orthopedic problems and pain may interfere with the data acquisition and should be taken into consideration.

QUANTITATIVE ANALYSIS OF GAIT IN NEUROLOGICAL GAIT DISORDERS

Rolf R. Diehl, Ute Schneider, Martin Konietzko & Michael Hennerici
Dept. of Neurology, University of Heidelberg, Klinikum Mannheim,
Theodor-Kutzer-Ufer, W-6800 Mannheim, Germany

Introduction

Human bipedal walking is a cyclic movement which can be divided into four phases: (1) single support phase left, (2) double support phase I (changing from the left to the right foot), (3) swing phase left and (4) double support phase II (changing from the right to the left foot). Each of these phases can specifically be disturbed in different gait disorders, and a quantitative analysis of the spatial and temporal parameters of the gait phases can help to describe and explain disturbed gait patterns. While in many studies spatial parameters such as stride length and angles of the knee- and hip-joints were measured (Elble et al. 1992) the present study focusses on measuring spatio-temporal properties of locomotion (gait-lines and cyclogram; Diehl and Hennerici 1990) in several gait disorders.

Methods

Our gait analysis system (Computer Dyno Graphy CDG, Infotronic, Tubbergen, The Netherlands) is based on the measurement of forces under the feet. It consists of a pair of shoes, each with eight force transducers distributed over the soles. The force values of each sensor are sampled with a rate of 50 Hz during a 20-second walking phase. These raw data enable an off-line calculation of the gait-lines of both feet (the course of the application point during the unrollment; see fig. 1A) and of the cyclogram (the course of the point of gravity resulting from vector addition of all 16 transducers when both feet are considered to be fixed in a virtual plane). The cyclogram is butterfly-shaped (see fig. 1B): The left and right vertical lines represent the single support phases of the gait-lines while the diagonale lines picture the shift of the point of gravity from one foot to the other one during the double support phases. Table 1 lists the spatial and temporal parameters that were derived from the gait-lines and cyclogram in the present study:

Table 1. Quantitative parameters calculated from the gait-lines and cyclograms.

Spatial parameters	abbreviation	description
length of the gait-lines	Lgl	averaged length over all gait-lines
lenght of the single support lines	Lssl	averaged lenght over all single support lines
relative lenght of the single support lines	Lssl-rel	Lssl/Lgl
variability of the gait-lines	Vgl	mean lateral/medial deviation of the gait-lines
variability of the double support lines	Vdsl	mean deviation of the diagonales in the cyclogram

Temporal parameters		
stance time	Tst	averaged duration of the floor contact of each foot
single support time	Tss	averaged duration of the single support of each foot
relative single support time	Tss-rel	Tss/Tst

A CDG was conducted in 60 normal subjects which were age matched to the patient groups, 20 patients with Parkinson's disease (PD), 14 patients with a cerebellar atrophy (CA) and 15 patients with a gait apraxia due to subcortical atherosclerotic encephalopathy (SAE).

Results

The results of our normal subjects and of the three patient groups are summarized in Table 2. Since there were no obvious left/right asymmetries in the gait patterns of patients we calculated for each parameter the mean of the left and right value.

In PD patients, all parameters differ significantly from the values of our normal control subjects. Both Lgl and Lssl are reduced with a disproportional larger decrease in Lssl yielding a significantly reduced Lssl-rel value (0.52 vs. 0.67). Both variability parameters Vgl and Vdsl are increased. The prolonged stance time in PD patients indicates a general slowing of the step frequency. Although Tss is also increased in PD patients, the relative single support time (Tss-rel) is smaller than in normals.

Table 2. CDG analysis in normal subjects and in the three patient groups. Mean and SD (in parentheses) are given for each parameter.

Parameters	Normals (N=60)		PD (N=20)		CA (N=14)		SAE (N=15)	
Lgl [arb. unit]	0.855	(0.045)	**0.722**	(0.106)	0.850	(0.056)	**0.809**	(0.113)
Lssl [arb. unit]	0.578	(0.078)	**0.376**	(0.109)	0.578	(0.092)	**0.344**	(0.118)
Lssl-rel	0.67	(0.08)	**0.52**	(0.11)	0.68	(0.09)	**0.43**	(0.13)
Vgl [arb. unit]	1.16	(0.34)	**1.46**	(0.46)	**1.87**	(0.72)	**1.84**	(0.64)
Vdsl [arb. unit]	1.53	(0.31)	**2.40**	(0.94)	**1.85**	(0.55)	**3.33**	(0.96)
Tst [sec]	0.589	(0.062)	**0.854**	(0.256)	**0.651**	(0.070)	**0.827**	(0.139)
Tss [sec]	0.464	(0.034)	**0.549**	(0.108)	**0.501**	(0.042)	**0.494**	(0.048)
Tss-rel	0.78	(0.06)	**0.66**	(0.08)	0.77	(0.04)	**0.61**	(0.09)

Fat printed numbers indicate a significant ($p<0.05$, Wilcoxon's test) difference to the normal values.

In CA patients, the absolute and relative spatial parameters (Lgl, Lssl, Lssl-rel) do not differ from the normal values. The most characteristic feature in these patients is an increase in both variability values (Vgl and Vdsl). The stance and single support times are increased, but the Tss-rel mean value (0.77) is normal.

The gait pattern of our SAE patients with a gait apraxia (fig. 1C and 1D) is similar to that of the PD patients. The relative single support lines and times are even more reduced than in PD, and the most significant difference to the normals and to the other gait disorder groups appears in the variability of the double support lines (Vdsl, the diagonal lines in the cyclogram in fig. 1D).

Discussion

A common feature in the three patient groups is a slowing of the step frequency, leading to increased stance and single support times. The hypokinetic (PD) and the apractic SAE gait is characterized by reduced absolute and relative single support lines. This fact cannot be explained by the reduced step frequency and velocity in PD and SAE patients since these variables are in normals only weakly correlated with Lssl or Lss-rel. PD and SAE patients differ mainly in the parameter "variability of the double support line" (Vdsl). SAE patiens have the largest Vdsl values, and this parameter seems to correlate with the gait insecurity in the apractic gait. A large increase in the variability of the gait-lines (Vgl) and to a smaller extent an increase in the variability of the double support line (Vdsl) picture the gait changes in patients with a cerebellar gait ataxia, while the remaining spatial or temporal parameters are not or only slightly different to the normal values. This means that in gait ataxia the steady-

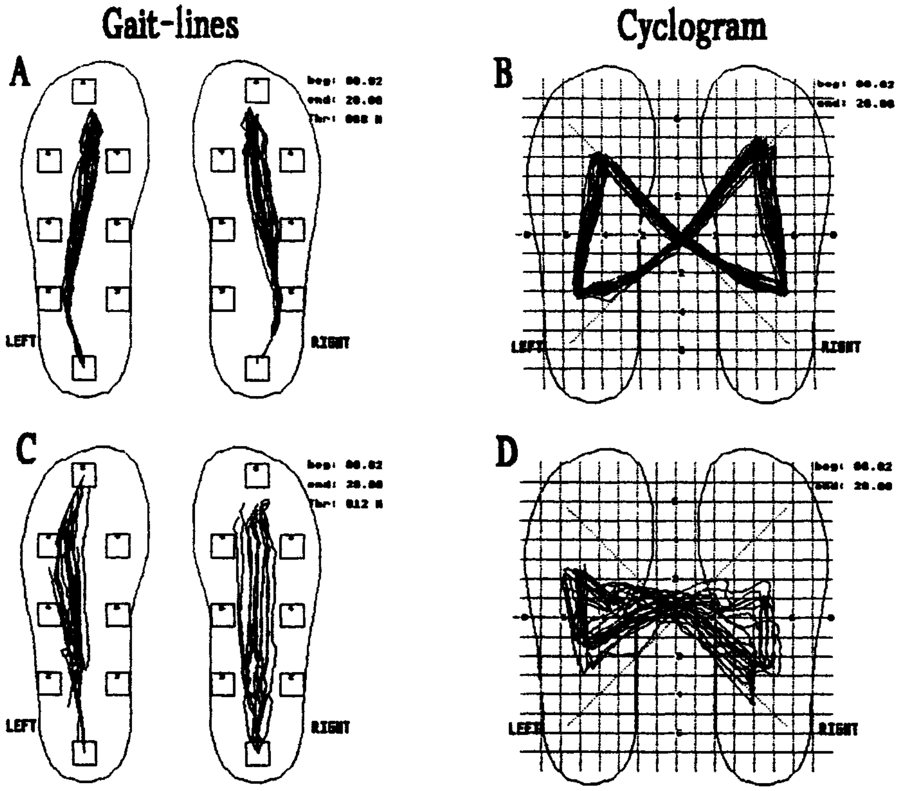

Figure 1. Gait-lines (A) and cyclogram (B) of a 49-years-old normal subject. Gait-lines (C) with increased variability and cyclogram (D) with reduced single support lines (vertical lines of the 'butterfly') and with increased variability of the double support lines (diagonale lines) of a 62-years-old patient with subcortical atherosclerotic encephalopathy.

ness of the unrollment is mainly affected but not the relative contributions of the single und double support phases.

In summary, the analysis of locomotion by quantitative description of gait-lines, cyclograms and the calculated parameters enable an illustrative representation of gait disorders. Specific alterations in single parameters of the CDG analysis describe the characteristics of different gait disturbances.

References

Diehl, R.R. & Hennerici, M. (1990). Quantitative analysis of gait patterns in neurological disorders. In Th. Brandt, W. Paulus & W. Bles (Eds.), Disorders of Posture and Gait 1990, Stuttgart: Georg Thieme Verlag, pp 354-357.

Elble, R.J., Hughes, L. & Higgins, C. (1992). The syndrome of senile gait. J. Neurol., 239, 71-75.