NEW METHOD FOR CONTINUOUS MEASUREMENT OF NOCTURNAL PENILE TUMESCENCE AND RIGIDITY

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ABSTRACT—A new technique for continuous recording of penile rigidity and tumescence has been developed. This methodology has been utilized in initial studies to define erectile function in both normal and impotent males. Accurate recording of tumescence and rigidity have been utilized to document the decline in erectile function associated with organic impotence.

Nocturnal penile tumescence measurement has enjoyed wide popularity during the past decade in the objective evaluation of patients with the complaint of impotence.[1-3] Increases in penile circumference associated with tumescence were recorded by a mercury strain gauge principally during periods of rapid eye movement (REM) sleep.[4] However, after an initial period of assumption that penile tumescence was equivalent to penile rigidity[1-3] evidence accumulated that the two events were not synonymous.[5-7] Impairment of rigidity could be disparate from tumescence and as the crucial measurement required a distinct and new methodology.

Various methods of measurement of penile rigidity have been developed including recording of penile buckling force.[4] This technique utilizing axial loading of the penile shaft gave an isolated measurement of maximal penile rigidity and required precise visualization by the observer of deflection or bending of the penile shaft. The technique did not provide documentation of the duration of penile rigidity nor the differences in rigidity that occur between penile base and shaft.

This article describes a methodology for continuous measurement of penile rigidity and tumescence. This method has the capacity to delineate between tumescence and rigidity and provides a more accurate measurement of both variables.

Technique

The system is composed of two major components: (1) an ambulatory nocturnal penile tumescence and rigidity data logging unit, and (2) a microcomputer with printer for processing and printing the data. The ambulatory unit has a loop transducer which self-adjusts in length to track penile circumference (Fig. 1). In the presence of tumescence, the loop modestly tightens around the penile shaft to measure penile rigidity by radial loading. The loop accommodates a penile circumference of 5 to 15 cm, which eliminates the need for multiple sizes. Patients tolerate the procedure without difficulty and frequent polysomnographic recordings have confirmed that the technique does not disturb sleep.

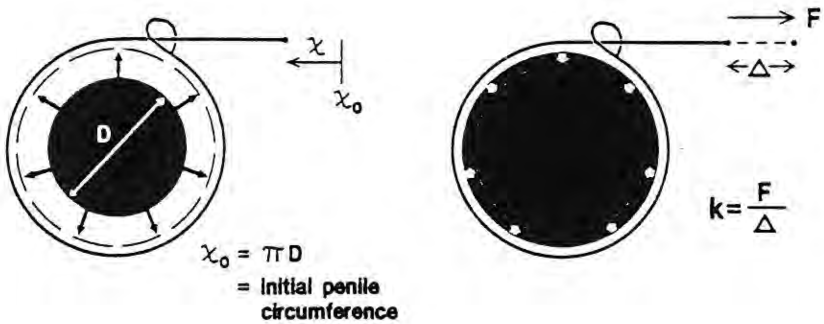

FIGURE 1. *Loop transducer for measuring concurrent tumescence and rigidity. Left diagram shows application of loop to erect penis where X is distance loop is moved in response to expansion. In figure on right, a force, F, is applied to loop, causing displacement D. Circumferential stiffness of penis is analogous to spring with spring constant $k = F/\Delta$.*

The loop cable is attached to a position-sensing potentiometer and a small DC torque motor (Fig. 2). The torque motor is energized briefly immediately preceding a position measurement to insure accuracy. Calibration of the loop and position-sensing assembly demonstrated an accuracy within 1 mm over the range of measurement. The transducer assembly is monitored and controlled by a battery-powered data logger and controller. The use of a microprocessor and memory chips provides minimal energy demands.

The operation of the ambulatory unit is as follows:

1. The ambulatory unit is strapped snugly to the subject's inner thigh, and the penile loop is comfortably fitted at mid-shaft of the penis. A baseline circumference measurement is performed.
2. The circumference of the penis is checked every fifteen seconds throughout the sleep cycle and the value stored in memory.
3. Rigidity was checked every three minutes by energizing the torque motor, and the value was stored.
4. If the circumference increased more than 3 mm, the rigidity sampling rate was increased to once every thirty seconds and those values were stored.
5. When circumference change falls below 3 mm during detumescence, rigidity checks were again decreased to once every three minutes.

The rigidity measurement so obtained was an indication of circumferential stiffness of the penis (Fig. 1). A cable force of 6 ounces was found to be sufficient for circumferential measurement. Twelve ounces were required to take a rigidity check, but were not so high as to be uncomfortable and thereby disrupt a regular sleep pattern. Tumescence was expressed in centimeters and rigidity in per cent relative to a hard rubber cylinder. Typically, two or three nights of data recording were required, similar to previous nocturnal penile tumescence monitoring techniques.

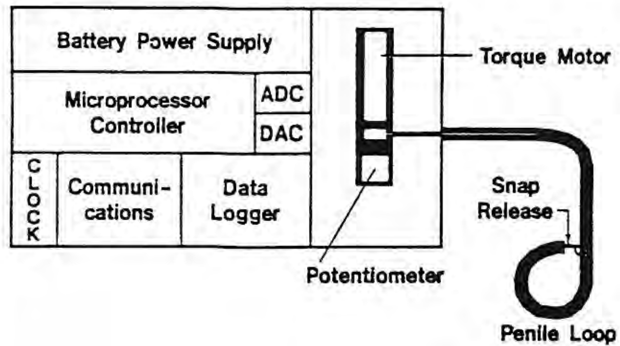

FIGURE 2. *Ambulatory system for operating loop transducer and data logging unit.*

At the conclusion of the nocturnal recording session, the data stored in the ambulatory unit were downloaded into the microcomputer (Apple II, Apple Computer, Cuperfina, CA) for processing graphic display and hard copy printing (FX-100, Epson Corporation, Torrance, CA) (Fig. 3). The data processing algorithm is written to permit point-by-point assessment of the data for investigational use. For routine data collection and display, an eight-hour recording session is printed onto one standard 8½ inch by 11 inch sheet of paper, thereby providing a composite pattern of rigidity and tumescence.

Eleven normal males and 11 males with the complaint of impotence were studied during three consecutive nights of recording. Nocturnal penile tumescence and rigidity were measured initially by application of the loop transducer to the midshaft of the penis and later by application to the base and distal shaft.

TABLE I. *Normal male/rigiscan data*

Pt Code	Nights of Testing	No. of Events	Maximum Duration of Single Event (Min)	Maximum Tumescence (Cm)	Value of Maximum Rigidity (%)
A23	1	4	62	5¼	95
A23	2	5	72	5⅛	58
A26	1	2	43	6	75
A26	2	4	51	5¾	68
Z26	1	3	65	5	80
Z26	2	4	90	4¾	80
B27	1	2	45	5	90
B27	2	4	60	5¼	78
A27	1	4	70	7	48
A27	2	5	60	5	64
A29	1	4	45	5	75
A29	2	5	60	5	70
A32	1	5	55	5½	100
A32	2	6	62	6	95
B32	1	4	70	5½	68
B32	2	4	73	5¾	60
B32	3	6	88	4½	75
A35	2	4	65	6	84
A35	3	3	50	6	82
A43	1	3	80	4	48
A43	2	3	67	4½	32
B43	3	6	77	5¼	98
B43	4	4	56	5¾	95
Range of values		2–4	43–90	4½–6¼	32–100
Mean		4	64	5⅓	74.4

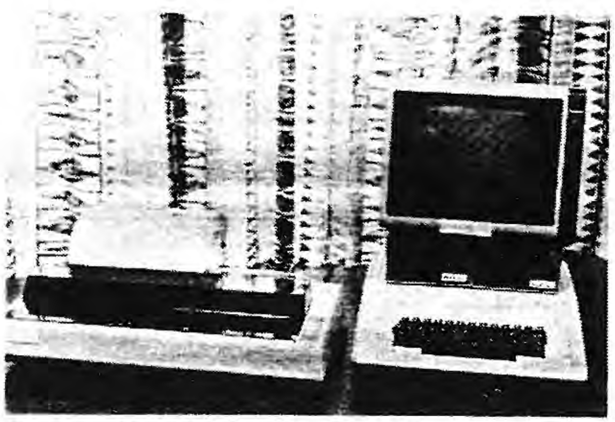

FIGURE 3. *Illustration of Apple computer and printer for downloading of data logging unit.*

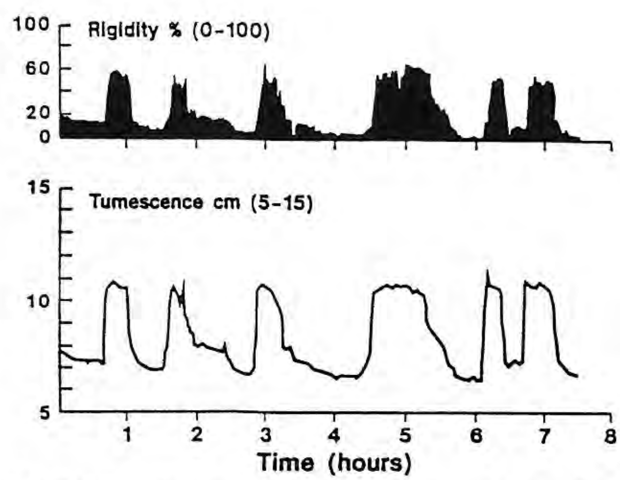

FIGURE 4. *Normal tracing of concurrent recording of tumescence and rigidity from mid-shaft of penis.*

Results

The technique was acceptable to all normal individuals and patients, and no side effects were reported. This was similar to that reported with the mercury strain gauge utilized in measurement of nocturnal penile tumescence.

In normal asymptomatic males penile rigidity was observed to have a more rapid rise time than tumescence and was usually not evident until maximum tumescence was attained. Table I is a record of the results obtained in healthy asymptomatic individuals. The mean number

TABLE II. *Symptomatic patients/rigiscan data*

Pt Code	Nights of Testing	No. of Events	Maximum Duration of Single Event (Min)	Maximum Tumescence (Cm)	Value of Maximum Rigidity (%)
HM64	1	0	0	0	0
HM64	2	1	0	1.4	18
HM64	3	0	0	0	0
JC53	1	0	0	0	0
JC53	2	0	0	0	0
JC53	3	0	0	0	0
DB50	1	3	18	4.8	39
DB50	2	4	32	3.6	49
DB50	3	5	45	4.0	47
OV55	1	3	17	2.4	31
OV55	2	0	0	0	0
OV55	3	3	28	4.2	68
AW53	1	1		2.0	14
AW53	2	5	40	2.7	20
AW53	3	3	34	2.9	37
IF63	1	5	20	4.0	74
IF63	2	4	12	3.5	48
IF63	3	6	12	3.8	53
CC64	1	2	15	3.4	52
CC64	2	2	19	2.7	46
CC64	3	4	20	3.7	49
RT56	1	4	39	6.2	96
RT56	2	4	63	5.4	68
RT56	3	6	41	4.8	93
JW67	1	3	28	2.3	38
JW67	2	3	55	4.3	79
JW67	3	6	28	4.2	68
LD48	1	3	50	5.4	74
LD48	2	2	35	4.2	46
LD48	3	4	40	5.2	62
AG62	1	5	27	4.2	62
AG62	2	4	30	4.2	58
AG62	3	3	48	3.8	78
Range of values		0–6	12–63	2.3–6.2	14–96
Mean		3.3	31.8	3.8	51.8

of nocturnal episodes of tumescence and rigidity was four, with a mean of sixty-four minutes for the maximum duration of a single event.

The mean value of maximum tumescence change was 5⅓ cm. This is in excess of that previously reported[4] and may be due to nonlinearity of the mercury strain gauge technique. Figure 4 is a representative sample of tumescence and rigidity recording in a normal healthy individual demonstrating the close association between tumescence and rigidity. The maximum rigidity had a mean value of 74.7 per cent.

Table II is a collation of results in males complaining of impotence and subjected to an evaluation schedule consisting of history, neurologic examination, and electrophysiologic tests of innervation of the genitalia. These latter studies consisted of measurement of the latency of the bulbocavernosus reflex,[8] the latency of the cortical pudendal evoked response,[9] and the conduction velocity in the dorsal nerve of the penis.[10] Blood pressure in the penile arteries was also measured utilizing a Doppler probe. Additional studies included serum testosterone and prolactin and patient interview by a neuropsychologist. The results of this test schedule will be the subject of a later report.

In these patients the mean number of nocturnal events was 3.3, the mean maximum duration of a single event 31.8 minutes, the

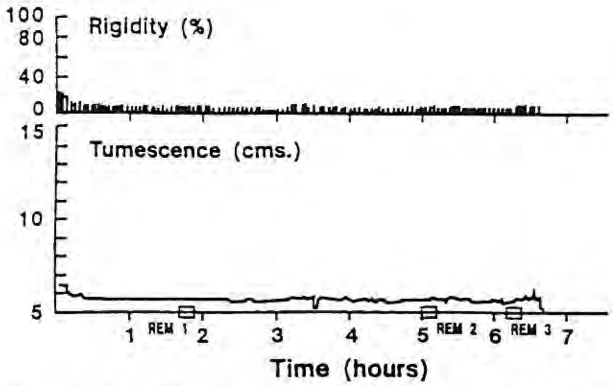

FIGURE 5. *Flat trace of tumescence and rigidity from impotent male. Accompanying polysomnographic studies showed three episodes of REM sleep.*

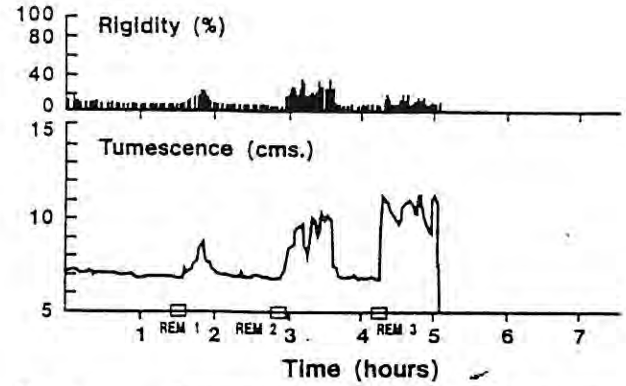

FIGURE 6. *Tracing from impotent male showing uncoupling or dissociation between tumescence and rigidity. Accompanying polysomnographic studies showed three episodes of REM sleep.*

mean value of maximum rigidity 51.8, and the mean maximum tumescence 3.8 cm. The most obvious abnormality on visual examination of the record was reduction in maximum duration of a single isolated event (Fig. 5).

Other abnormalities of tumescence and rigidity in impotent males included uncoupling or dissociation between these two events (Fig. 6). The precise incident of this event in a population of impotent males requires further study.

Comment

The continuous recording of penile rigidity rather than tumescence has been the aim of the development of this technology. Rather than recording circumferential expansion associated with penile tumescence, penile rigidity was considered to be the critical variable in the evaluation of impotent males. However, in the conduct of the study, comparison between the two modalities was initiated in recognition of how accepted NPT has become in the study of impotence. In addition, the new technique of nocturnal tumescence measurement described was linear in contrast to prior studies utilizing the mercury strain gauge. Duration of tumescence and values of maximum expansion were increased over those previously reported.[1-4] The validity of radial loading as a methodology for assessment of penile rigidity has been demonstrated by plotting axial buckling force measurements against maximum values of rigidity measurements in the same patients (Fig. 7). The plot of these data is linear and documents the validity of radial loading as a technique for assessing penile rigidity.[11]

Studies of normal individuals showed numerous episodes of tumescence and rigidity during

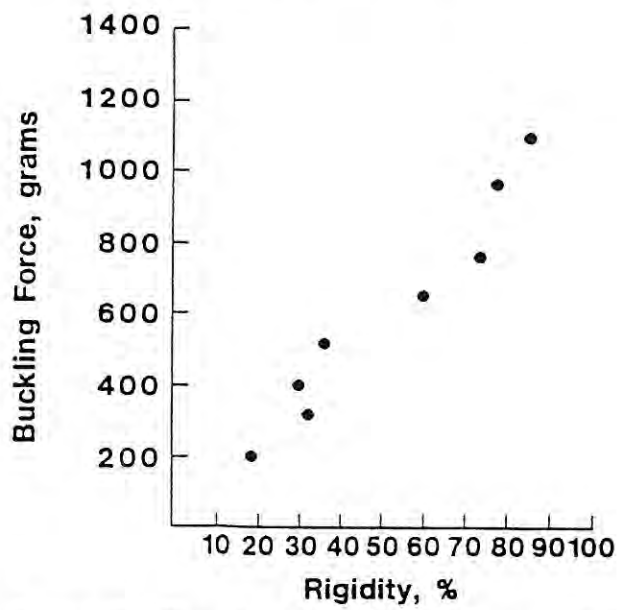

FIGURE 7. *Plot of axial buckling force vs radial rigidity.*

a night of restful sleep. Rigidity rapidly appeared after attainment of maximal tumescence and was always associated with a tumescence episode. In these initial studies recordings were made from a mid-shaft location of the penis. In future studies concurrent recordings of tumescence and rigidity will be made from the base and distal shaft of the penis.

Abnormal recordings were clearly distinguished from normal by reduction in duration and amplitude of maximal rigidity. The most critical variable in these initial studies appeared to be reduction in maximum amplitude of a single event. The number of nocturnal events appeared to be less affected.

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