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Nocturnal Penile Tumescence

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The evaluation of nocturnal penile tumescence (NPT) has for a number of years been considered the best noninvasive method for differentiating organic from psychogenic impotence. The measurement of NPT has been variously performed with mercury strain gauges, stamps, snap-gauge bands, and now with sophisticated instrumentation that measures penile tumescence and rigidity continuously during sleep.

HISTORY

In 1940, Halverson described NPT in infants;[13] 4 years later, this same phenomenon in adults was described by Ohlemeyer and associates.[25] It was not until 1953 that Aserinsky and Kleitman first described rapid eye movement (REM) sleep[1] and 1957 that Dement and Kleitman described the relation of REM sleep to dream activity.[7] Fisher and coworkers in 1965 and Karacan and colleagues in 1966[15] reported a relation between REM sleep and erections, and Karacan in 1970 was the first to suggest that the erection–REM relation might provide the basis for a tool in "diagnosis and prognosis in impotence."[16] Since that time, there have been many articles that have described NPT in boys and men who are either healthy or have various diseases.

In the study of males age 3 to 79 years, Karacan and coworkers determined that there is a rapid decrease in total sleeping time throughout the teen years with no significant change from 20 to 50 years of age.[12] There then is a slight increase in total sleep time in 60- and 70-year-old men. Total REM time decreases throughout the preteen and teen years and in subsequent years remains stable at approximately 100 minutes per night. Total tumescence time decreases from age 13 through age 79. Tumescence time during these years is approximately 1½ hours per night, or 20 per cent of total sleep time. The increase in total tumescence time during the prepubertal and very early pubertal years is associated with an increase in non-REM (NREM)-related tumescence as REM sleep decreases. In addition, there is a steady although slight decline in REM-related tumescence from age 20 to the 70s with an associated increase in NREM-related tumescence. In the 20- to 29-year-old population, the average length of an NPT episode is 38 minutes, whereas the average length of the NPT episode is 27 minutes in the 61- to 67-year-old population.[20] Not all NPT episodes are associated with a full erection and, in fact, the incidence of partial erections increases during NPT with advancing age.

There have been numerous articles describing abnormal NPT results in patients with various diseases, a few of which are diabetes,[18,19] alcoholism,[31] chronic obstructive pulmonary disease,[10] and narcolepsy.[28,21] The value of NPT has also been reconfirmed by a number of reports.[26,33,36]

In short, NPT is a naturally occurring, nonsexually stimulated phenomenon whose mechanism is presumed to be similar to that of the sexually stimulated erection. It most often occurs around REM sleep but is also present during NREM sleep. Normal NPT in a person with sexual dysfunction would suggest psychogenic impotence, and an abnormal recording would suggest organic impotence.

PROBLEMS IN THE INTERPRETATION OF NPT RESULTS

The validity of NPT monitoring has been questioned by numerous authors. Wasserman

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and associates state that although NPT is a useful test in differentiating psychogenic and organic impotence, there is a need to confirm the diagnosis of psychogenic or organic importance independent of NPT monitoring.[34] Those authors, along with others,[19,22,27,29,35] elucidate the need to measure penile rigidity also and point out the inadequacy of noting only circumferential change as performed by NPT monitors. In an article by Wein and coworkers, 42 per cent of patients who had normal circumferential change on NPT had rigidity inadequate for vaginal penetration as determined by direct observation.[35] Had this latter test not been performed, an incorrect diagnosis of psychogenic impotence would have been made.

Other authors have suggested that sleep can be disrupted by such disorders as sleep apnea, periodic leg movements, and nocturnal myoclonus.[27,29] With these conditions, NPT may be significantly reduced as a result of these sleep disorders and not because of abnormal erectile function. Those authors therefore felt that NPT studies need to be performed in a sleep laboratory. NPT results may also be spurious because of the anxiety of the testing situation, the "first-night effect," REM changes because of the ingestion of medicines, and severe depression.[32]

The evaluation of the man with sexual dysfunction has not been uniform, and it is therefore difficult to compare the findings in the various centers interested in the evaluation of sexual dysfunction. By utilizing a uniform evaluation in more than 1,100 men with sexual dysfunction, however, we have minimized most of the concerns about NPT. Our evaluation includes routine blood chemistries and tests to evaluate the pituitary-gonadal axis as well as Doppler determination of blood flow in the penis. In addition, electrophysiologic tests such as the nerve conduction velocity of the dorsal nerve of the penis,[4] pudendal evoked response,[12] and measurement of the bulbocavernosus reflex[30] are performed. Pharmacoarteriography and dynamic corporacavernosometry and corporacavernosography are performed when indicated. I feel that the performance of this battery of tests, as much as possible, has indeed validated the results of NPT monitoring when the latter is done with the RigiScan (Dacomed Coprporation, Minneapolis, Minnesota), which measures continuous tumescence and rigidity. In addition, the testing can almost always be performed in an ambulatory setting without EEG monitoring as long as there is some amplitude in tumescence and rigidity and the testing is done for two to three nights.

METHODS OF MEASURING NPT

The initial measurement of NPT utilized one mercury-filled strain gauge placed either at the tip or the base of the penis during sleep. This practice was modified and standardized so that NPT monitoring utilized two silicone mercury-filled rings, one of which was placed at the base of the penis and the other just proximal to the corona. These initial monitors measured changes in penile circumference only. It was felt that changes in circumference of less than 16 mm were characteristic of partial erections. Erections of 16 mm or greater were believed to be adequate for vaginal penetration, as it was thought that erections adequate for intromission must be at least 80 per cent of maximum fullness. A full erection was characterized by circumferential changes of 20 mm, and thus the aforementioned 16 mm represented 80 per cent of the 20-mm maximum value.[19]

Ambulatory use of NPT monitors soon became extremely popular; however, the test measured only circumferential change and not rigidity. Calibration of the strain gauges is not uniform, and artifacts are common as a result of patient activity during sleep. Firmness of the penis during an erection has been measured as buckling pressure by Karacan and associates with the use of a pressure device pressed against the glans; the pressure at which the penis first buckles is noted by the device, which is a large cylinder with a rubber cap on one end and a sphygmomanometer on the other end.[20]

Barry and associates in 1980 proposed a simple test using stamps in an attempt to overcome the false-positive recordings of the NPT monitor caused by movements during sleep and to avoid the continual breakage of the strain gauges.[2] Stamps measuring 1½ × 1 inch were wrapped around the penis, and the patient was asked to sleep wearing shorts. If, when he awoke, the stamps were broken along the perforations, this was considered evidence of a good erection; and thus the "stamp test" could be a good screening tool for the diagnosis of sexual dysfunction. Marshall and associates corroborated the validity of the stamp test as a screening test for men with sexual dysfunction[23] and a similar standardized test was described by Bertini and Boileau.[3]

In 1983, the Snap-Gauge (Dacomed Corporation, Minneapolis, Minnesota) was described as a simple test to measure penile rigidity.[8] Three color-coded plastic sheets arranged in parallel are mounted on a Velcro fastener. The sheets are designed to rupture at a force constant of 10, 15, and 20 ounces and correspond to pe-

nile buckling pressures[20] and intracavernosal pressures[24] of 90 to 180 mm Hg. It is thought that if there is no element breakage during a restful night of sleep that insignificant erectile activity has occurred. If only the first element (blue; 10 ounces) breaks, there is minimal rigidity, and although intercourse would be possible, intromission would not be easy. If the second element (red; 15 ounces) breaks, sufficient rigidity for intromission is probable, and, finally, if the last element (white; 20 ounces) breaks, excellent rigidity is present. The Snap-Gauge can be utilized as a screening tool but does not denote the duration or number of tumescent events during the night it is used.

RIGISCAN MONITORING

In 1985, Bradley and Timm described the first use of the RigiScan, an ambulatory monitor that measures concurrent penile tumescence and rigidity.[5] It was developed to overcome the deficiencies of the standard NPT monitors with the realization that penile circumference is not synonymous with penile rigidity.

The RigiScan is comprised of two components: an ambulatory nocturnal penile rigidity and tumescence data-logging unit (Fig. 1) and a microcomputer with a printer that processes and prints the data. The data-logging unit is strapped to the medial aspect of the thigh and has a base and tip loop that can accommodate a penile circumference range of 5 to 15 cm. Each loop contains a cable that, when the machine is turned on, will tighten slightly to delineate penile circumference in a characterization session while the patient is instructed on how to use the machine. When used at home during sleep, the loop tightens every 15 seconds to measure penile circumference and then loosens so as not to impede erectile activity. Penile circumference is measured in centimeters, and when there is a change in circumference of 1 cm, the RigiScan will take a rigidity reading every 30 seconds. This measurement will be repeated until the change in tumescence is less than 1 cm, which causes the machine to take rigidity readings at the normal 3-minute interval. To measure rigidity, the loops tighten with a constant force of 10 ounces. When this force is applied to soft tissue, the cable displacement will be greater than when the same force is applied to a solid object. Therefore, a rigidity of 100 per cent represents no linear displacement of the loop when a force of 10 ounces is applied to a solid object. Rigidity is expressed in per cent and is determined by cross-sectional response to radial compression. Rigidity has previously been expressed as penile buckling force, which is a measure of axial rigidity. The RigiScan denotes penile rigidity by measuring radial rigidity. Therefore, by utilizing dynamic corporacavernosometry, Frohrib and Goldstein performed measurements of axial rigidity and radial rigidity at various constant corporal-body pressures.[11] Their conclusion was that there is a distinct functional relation between axial and radial rigidity, thus making the measurement of radial rigidity by the RigiScan meaningful in the clinical setting. In addition, those investigators confirmed the importance of measuring rigidity; their studies showed that rigidity is a function of corporal-body pressure. Rigidity is not functionally related to changes in penile circumference. The RigiScan ambulatory unit can collect data for a half-hour characterization session and three 10-hour monitoring sessions.

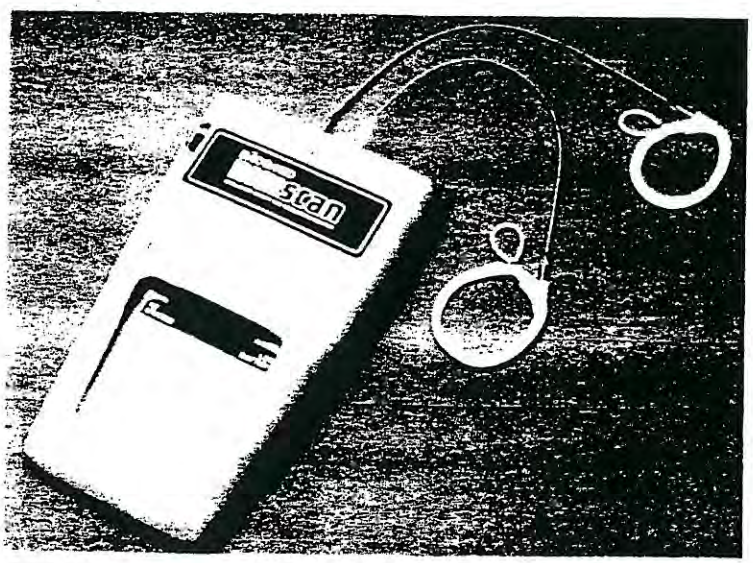

Figure 1. The RigiScan ambulatory 2-pound unit that simultaneously measures penile tumescence and rigidity.

The second component is an IBM PC or IBM PC–compatible computer with a printer that downloads the contents of the memory chip of the first component and delivers an 8½ × 11 inch sheet of paper with the 10-hour result of a night's use of the RigiScan. The data and start and stop times of the test are included in the printout so that malingering can be detected. The software has the ability to amplify the 10-hour display on the computer screen, thus facilitating data processing and analysis of specific events.

As mentioned, the RigiScan has been utilized in our practice in the evaluation of more than 1,100 patients. Patients are instructed to avoid naps, alcohol, and all but the most necessary drugs during the evaluation period. These steps augment the chances for restful sleep and will decrease the chances for spurious results that may arise because of short or restless sleep. The machine is utilized on three (occasionally two) successive evenings to minimize the first-night effect and with the understanding that NPT varies from one night to the next.

When evaluating tumescence, the normal parameters of the RigiScan include a change in circumference of 3 cm or greater at the base of the penis and 2 cm or greater at the tip of the penis (Fig. 2). Much more important than circumferential change, however, is the measurement of rigidity. A rigidity of 70 per cent or greater represents a nonbuckling erection, whereas rigidities below 40 per cent represent a flaccid penis. Rigidities between 40 per cent and 70 per cent represent various degrees of stiffness, and those rigidities approaching 70 per cent will enable intromission.

The interpretation of the RigiScan includes viewing the printout for absent or reduced amplitude of erectile activity as far as enlargement and rigidity are concerned. Dissociation[6,14] (Fig. 3) is an abnormal condition where penile rigidity is greater at the base than at the tip. Uncoupling (Fig. 4) is an abnormal condition where normal or near-normal circumferential expansion occurs in the absence of normal rigidity. This latter condition reveals the importance of measuring rigidity and would have accounted for an incorrect diagnosis if an NPT monitor not measuring rigidity has been utilized.

The RigiScan also notes the duration of the NPT event on the horizontal axis of the printout sheet. When viewing rigidity, confluent vertical lines, each one representing 1 minute 15 seconds, combine to represent the length of the event. Most events last for at least 15 minutes. Studies are now being performed to determine the importance of the duration of each event. We have had a number of patients, however, who have had short bursts of reasonable-quality rigidity that have lasted less than 3 minutes who have turned out to have corporal venous leak. Therefore, extremely short periods of rigidity may prove to be abnormal, especially when coupled with a history of being able to obtain but not maintain an adequate erection.

The RigScan can also be used for real-time monitoring in situations where erections obtained with sexual stimulation need to be documented or the efficacy of our pharmacologic erection program needs to be tested. The

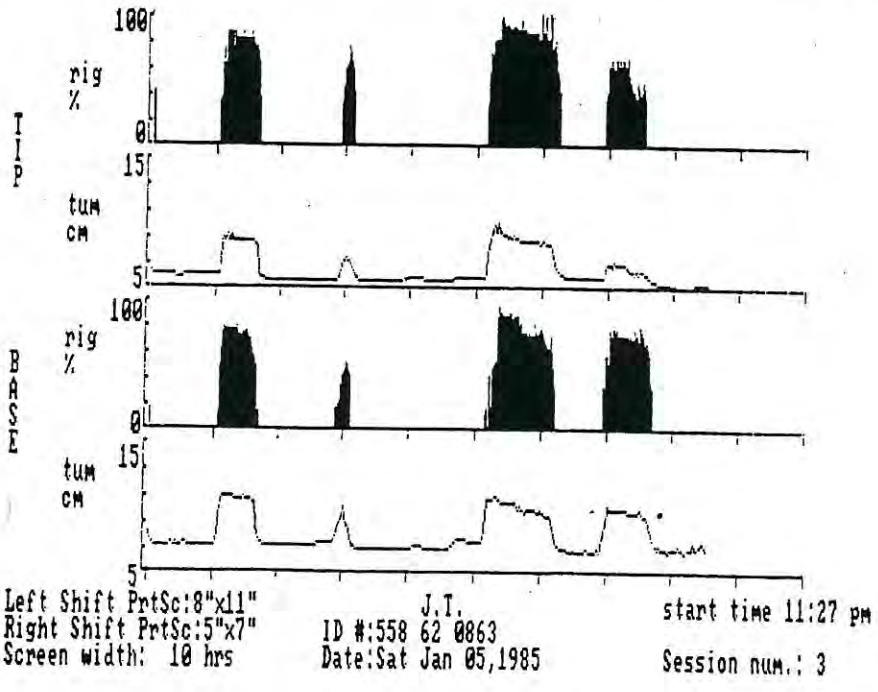

Figure 2. Normal RigiScan showing four events of nocturnal penile tumescence. The third event shows a change in circumference of 3.5 cm at the base and tip of the penis. There is 86 per cent rigidity at the base of the penis and 93 per cent rigidity at the tip of the penis during this event (tum = tumescence; rig = rigidity).

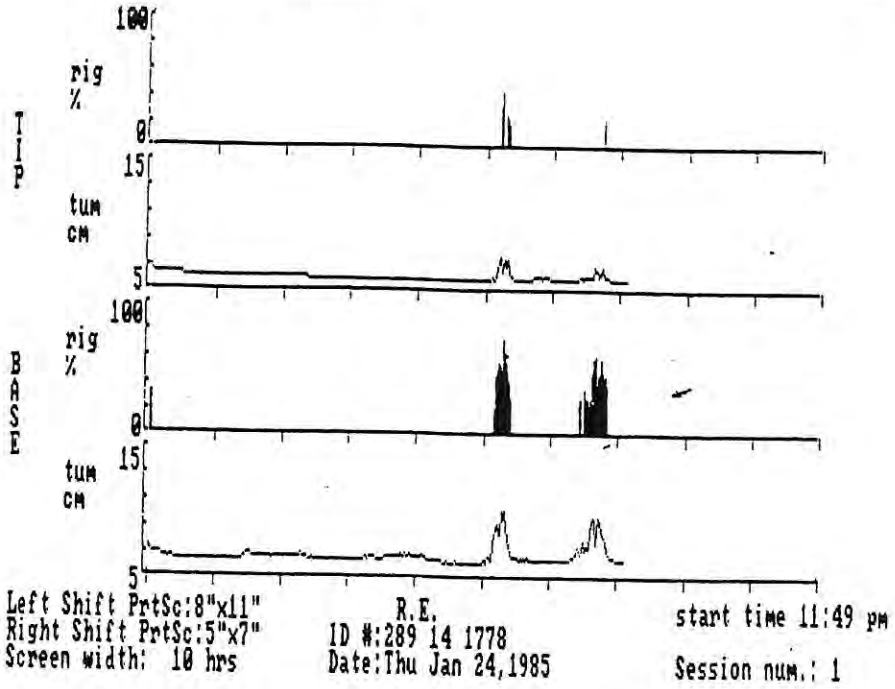

Figure 3. Dissociation. The RigiScan shows poor rigidity at the tip of the penis compared with the base.

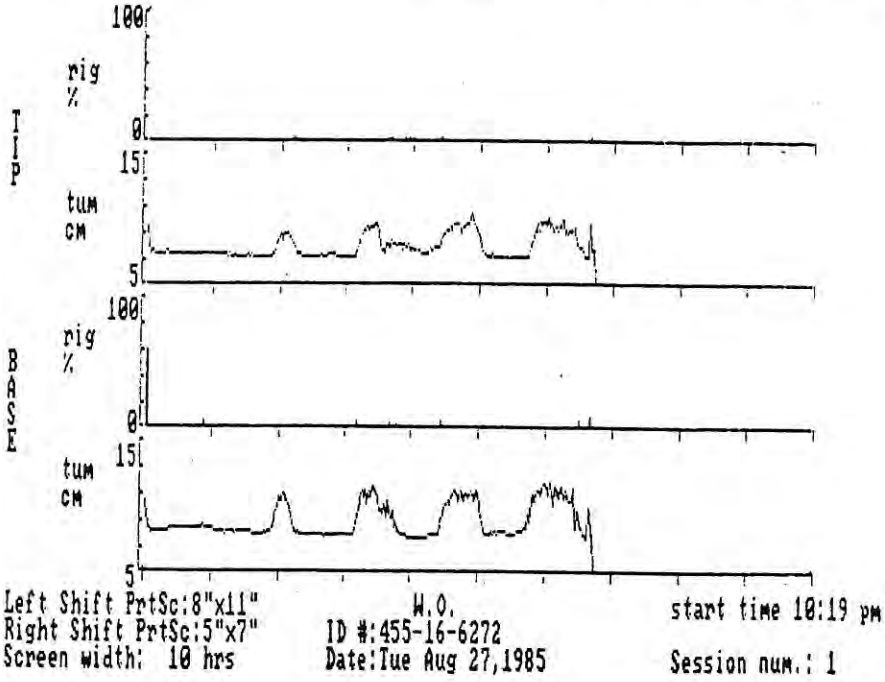

Figure 4. Uncoupling. Good tumescence associated with poor rigidity.

RigiScan can also be used to test the success of certain treatments including penile revascularization and venous ablation and is especially helpful because of the psychologic overlay that can develop in any man with impotence.

SUMMARY

NPT monitoring remains the best single noninvasive examination to differentiate organic from psychogenic impotence. The need to measure rigidity concurrently with tumescence during NPT is well known, thus making monitoring with the RigiScan, which measures these parameters, the procedure of choice when evaluating NPT.

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