Increased Sexual Health After Restored Genital Sensation in Male Patients with Spina Bifida or a Spinal Cord Injury: the TOMAX Procedure

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Abbreviations and Acronyms

BCR = bulbocavernosus reflex
DNP = dorsal nerve of penis
SB = spina bifida
SCI = spinal cord injury
SL = spinal lesion
VAS = visual analogue scale

Accepted for publication October 9, 2012.

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Purpose: In this study we prospectively investigated the contribution of restored penile sensation to sexual health in patients with low spinal lesions.
Materials and Methods: In 30 patients (18 with spina bifida, 12 with spinal cord injury, age range 13 to 55 years) with no penile sensation but good groin sensation the new TOMAX (TO MAX-imize sensation, sexuality and quality of life) procedure was performed. This involves microsurgical connection of the sensory ilioinguinal nerve to the dorsal nerve of the penis unilaterally. Extensive preoperative and postoperative neurological and psychological evaluations were made.
Results: A total of 24 patients (80%) gained unilateral glans penis sensation. This was initially felt as groin sensation but transformed into real glans sensation in 11 patients (33%). These patients had better overall sexual function ($p = 0.022$) and increased satisfaction ($p = 0.004$). Although 13 patients (43%) maintained groin sensation, their satisfaction with sexuality was only slightly less than that of those with glans sensation. Improved sensations helped them manage urinary incontinence, thereby improving personal hygiene and independence. Most patients felt more complete and less handicapped with their penis now part of their body image. They also reported having more open and meaningful sexual relationships with their partners.
Conclusions: Tactile and erogenous sensitivity was restored in the glans penis in patients with a low spinal lesion. This new sensation enhanced the quality of sexual functioning and satisfaction. The TOMAX procedure should become standard treatment for such patients.

Key Words: spinal dysraphism, spinal cord injuries, sexuality, pudendal nerve, spinal nerve roots

Most male patients with spina bifida or a spinal cord injury do not have any sensation in the penis, although most can achieve erection with ejaculation.[1–3] Despite having erectile function and an active interest in sex,[1] the absence of penile sensation leads to frustration. In the quality of life improvements desired by patients with SL, regaining sexual function has the highest priority.[4,5] Many studies have reported decreased sexual health,[5–7] but no study to our knowledge has dealt specifically with the role of penile sensation in patients with SL.

Normally sensory impulses from the glans penis are transmitted through dorsal penile and pudendal nerves to sacral nerve roots 2 to 4. They continue through the spinal cord to the

0022-5347/13/1892-0626/0
THE JOURNAL OF UROLOGY®
http://dx.doi.org/10.1016/j.juro.2012.10.020
Vol. 189, 626-632, February 2013
Printed in U.S.A.

sensory cortex unless interrupted by a spinal lesion. We hypothesized that restoring penile sensation in patients with SL would contribute to their sexual satisfaction and health, and designed an operative procedure called TOMAX. Because of the high spinal entry level (L1) of the ilioinguinal nerve we were able to use this nerve as a neurological bypass to restore penile sensation in 3 patients with low lesion SB.[8] The sensory information from the glans was rerouted via the DNP and ilioinguinal nerve to the sensory cortex. Our first 3 patients claimed that the penis became more integrated in their body image, 2 found masturbation more meaningful and 1 became more sexually active. These promising results justified this study to test our hypothesis and investigate the outcome of the TOMAX procedure in 30 patients with a low spinal lesion.

MATERIALS AND METHODS

Patient Selection and Procedure

With ethics committee permission we selected 30 patients with SL with no penile sensation but normal groin sensation. They gave written consent, were assessed as psychologically stable and had no negative sexual experiences. We used our operative procedure called TOMAX,[8] in which the sensory ilioinguinal nerve was cut distally in the groin and joined by microneurorrhaphy to the divided DNP at the base of the penis. All interventions were performed by 1 plastic surgeon (MLEO). The patients were evaluated preoperatively and twice postoperatively after a median (range) of 6 (5 to 10) and 15 months (11 to 24) when no further sensory improvement was expected.

Sensitivity Testing

The right and left halves of the shaft and glans of the penis and both groins were subdivided into 3 regions for testing. We used neurological sensory tests for touch (pointed vs blunt stimuli) and temperature stimuli (at 37C and 4C) to determine what sensation was present.[9,10] The patient was blindfolded and each region was stimulated 3 times at random intervals. If all the stimuli were correctly experienced all 3 times, we concluded they had sensation.

Quantitative fine touch sensitivity was determined using Semmes-Weinstein monofilaments (North Coast Medical Supply, Morgan Hill, California).[9,11,12] The monofilaments of ascending intensity (2.83 to 4.74, corresponding target force 0.07 to 6 gm) were applied perpendicular to the skin of the groin and glans for about 1.5 seconds, with the threshold being the smallest stimulus identified correctly. The most sensitive region was taken to represent the amount of fine touch sensitivity for the groin and glans. Sensitivity testing was repeated postoperatively. Apart from the presence of sensation, we noted where the stimulus of the glans was actually experienced in the groin, penile shaft or on the glans itself.

Bulbocavernosus Reflex

To preserve reflex erections we decided not to operate bilaterally but to keep 1 DNP intact. We determined if the right or left DNP still had a role in erectile function by studying the integrity of the reflex arc S2–S4 bilaterally using needle electromyography-BCR measurements.[13] In this reflex the perineal bulbocavernosus muscle contracts to DNP stimulation. If the BCR was bilaterally positive or negative, we could operate on either side, but if it was unilaterally positive we operated on the contralateral negative side.

Psychological Functioning and Sexuality

Psychological functioning and sexuality were measured by a clinical psychologist trained in sexology, using the HADS (Hospital Depression and Anxiety Scale) questionnaire to determine patient level of distress[14] and the SCL-90-R® (Symptom Checklist-90-Revised) to measure psychoneuroticism.[15] We used the GAS (Groninger Arousability Scale) to assess the ability to experience the stages of the sexual response cycle.[16] The psychologist also used a semi-structured interview to assess sexuality and sexual satisfaction. The plastic surgeon interviewed the patients to obtain a clinical perspective on sexual and genital functioning and urinary continence management.

Statistical Analysis

Categorical data are presented as n and tested using Fisher's exact test (using SISA [Simple Interactive Statistical Analysis] for more than 2 scoring categories, http://www.quantitativeskills.com/sisa) or the McNemar test for unpaired or paired comparisons, respectively. Continuous data are presented as median (range) and were tested using the Mann-Whitney U test or the Wilcoxon signed rank test for unpaired or paired comparisons, respectively. All analyses were performed 2-tailed with alpha 0.05 significant using PASW® version 18 (SPSS® Inc.) unless stated otherwise.

RESULTS

Patient Characteristics

From 2001 to 2009 we operated on 30 patients with SL. The ilioinguinal nerve could not be used in 3 patients with SCI (median age 41 years, range 21 to 55; lesion level L2, range L1–L5; median time since injury 5 years, range 5 to 12) as it was absent bilaterally in 2 patients and both nerves were severely damaged in another patient. The other 27 patients were successfully operated on and followed including 18 SB (median age 18.5 years, range 13 to 40; level of lesion L4, range L2–S1) and 9 SCI (median age 30 years, range 21 to 42; level of lesion L2, range T12–L4; median time since injury 5 years, range 2 to 15). Based on BCR measurements we operated on 16 left and 11 right sides.

Sensation in Glans Penis

In many patients the first sign of unilateral penile sensation was being aware of the cold urinary catheter being introduced into the urethra after 2 to 4 months. This was followed by an electrical/hypersensitive sensation and later a tingling sensation of

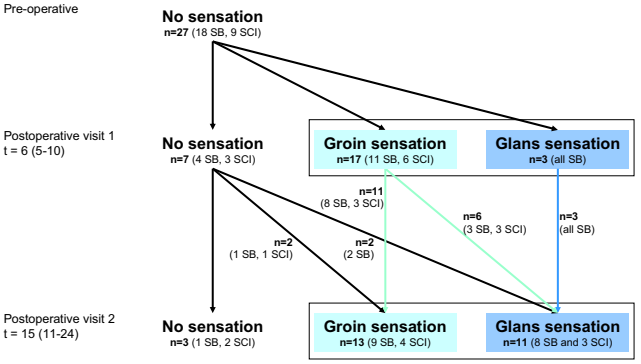


Figure 1. Development of sensation. *t*, median months (range). Groin sensation means touching glans was experienced as if groin was being touched. Glans sensation means touching glans was experienced as if glans itself was being touched.

the glans, experienced as if the groin was being touched. This glans penis sensation then changed into a nonpainful, normalized sensation, which stayed in the groin or transformed to actual glans sensations experienced at the glans itself. No sensation or only a little sensation developed at the penile shaft. This resulted in unilateral glans penis sensation at the second postoperative visit in 24 of 30 (80%) patients, which was experienced as groin sensation in 13 of 24 (54%) and as glans sensation in 11 of 24 (46%). Figure 1 shows the development of sensation with time.

Semmes-Weinstein

Reliable and reproducible Semmes-Weinstein monofilament glans and groin sensory tests were performed in 13 and 15 patients, respectively. Postoperative glans sensation at the second visit increased from absence to having sensations in the range of 0.4 to 6 g (median 1) (fig. 2, *A*). Donor groin sensitivity was decreased in most patients compared to preoperative sensitivity (fig. 2, *B*), but none missed the groin sensation or experienced long-term discomfort or pain.

Sensory Changes Affecting Urinary Continence Management

Of the 22 patients using self-intermittent catheterization 14 felt a nonpainful, cold sensation in the urethra when the catheter was introduced. Two patients noticed that their condom catheter/diaper became wet while 4 could actually feel urine passing through the urethra. Two patients could partially empty their bladder.

Changes in Mechanism of Erection/Ejaculation

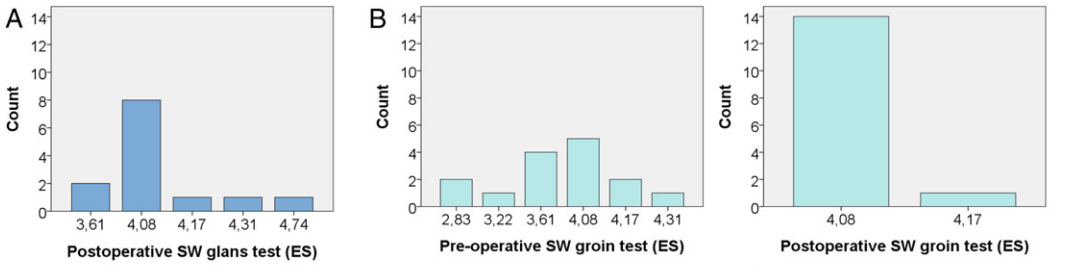
All patients retained the preoperative ability to have an erection and ejaculations. In 5 patients the mechanism of erection changed from a psychogenic-only pathway into a combined psychogenic reflex pathway postoperatively ($p = 0.063$, table 1). This change was seen significantly more in patients in whom actual glans sensations developed ($p = 0.036$, table 2).

Psychological/Sexological Assessment

Postoperative psychosexual evaluations were performed in 19 of 27 patients. Of the 8 patients who no longer participated 3 had no sensation, 4 had tactile sensations but without real gain and 1 had erogenous sensation with results similar to those described.

Psychological Functioning

Preoperatively these 19 patients reported no significant distress or psychopathology (mean HADS-A score 4.06, mean HADS-D score 2.78, mean SCL-90-R score 117), with scores comparable to those of the general population.[15,17] After surgery the mean scores were even lower but the changes were not significant (mean HADS-A 2.8, mean HADS-D 2.5, mean SCL-90-R 111.8).



Distribution of postoperative SW glans sensory test results at 2nd visit (n=13).

Distributions of pre-operative (n=15) and postoperative at 2nd visit (n=15) SW groin sensory tests. P = 0.135, by Wilcoxon signed ranks test.

Figure 2. Quantification of sensation by Semmes-Weinstein (*SW*) monofilaments (touch test sensory evaluators). *A*, distribution of postoperative SW glans sensory test results (13) at visit 2. *B*, distributions of preoperative (15) and postoperative/visit 2 (15) SW groin sensory tests (Wilcoxon signed rank test $p = 0.135$). *ES*, evaluator size. SW evaluator sizes used (target force in gm) were 2.83 (0.07), 3.22 (0.16), 3.61 (0.4), 3.84 (0.6), 4.08 (1), 4.17 (1.4), 4.31 (2), 4.56 (4), 4.74 (6). Evaluator size was inversely related to amount of sensation.

Table 1. *Comparison of preoperative and postoperative results*

	Preop	Postop (visit 2)	p Value
	Data from clinician (27 pts)		
Median mos from operation (range)		15 (11–24)	Not applicable
No. glans sensory test:			
Sensation (no/yes)	27/0	3/24	Not applicable
Sensation yes, localization of sensation (groin/glans)*	Not applicable	13/11	Not applicable
No. penile function:			
Erection (no/yes)	1/26	1/26	1.000
Erection yes, origin of erection (psychogenic/reflex)†	21/5	16/10	0.063
No. ejaculation (no/yes)	4/23	4/23	1.000
No. partner:			
Sexual partner (no/yes)	18/9	13/14	0.063
Sexual partner yes, introduction in vagina felt (no/yes)	9/0	6/8	Not applicable
	Data from psychologist (19 pts)		
No. arousal:			
Strength of arousal (decreased/no change/increased)		0/7/12	Not applicable
Erection during arousal (decreased/no change/increased)		1/18/0	Not applicable
No. masturbation:			
Masturbation (no/yes)	7/12	2/17	0.125
Masturbation yes, orgasm (no/yes)	1/11	3/14	1.000
Masturbation frequency/mo (decreased/no change/increased)		0/7/12	Not applicable
Ease of erection (decreased/no change/increased)		0/11/8	Not applicable
Ease of achieving orgasm (decreased/no change/increased)		1/10/8	Not applicable
Sensation of orgasm (decreased/no change/increased)		1/10/8	Not applicable
No. partner:			
Sexual partner (no/yes)	12/7	7/12	0.063
Intercourse (frequency/mo)	0 (0–12)	2 (0–70)	0.002‡
Satisfaction (VAS score)	8 (6–9)	9 (4–10)	0.039‡
Stiffness erection (VAS)	8 (1–10)	9 (4–10)	0.008‡
Satisfaction with sexuality:			
Satisfaction with erection during masturbation (VAS)	6.5 (0–10)	8 (0–10)	0.016‡
Satisfaction with sexual function (VAS)	6 (1–9)	8 (2–10)	0.123
Satisfaction with sexual life (VAS)	4.5 (1–8)	6.5 (1–10)	0.002‡
Satisfaction with sexual life in general (sum of 3 VAS scores above)	17 (3–26)	24 (3–29)	0.004‡
Overall sexual functioning (total GAS score)	37 (28–50)	33 (24–46)	0.022‡

* Groin defined as groin sensation: Touching the glans is experienced as if the groin was being touched. Glans defined as glans sensation: Touching the glans is experienced as if the glans itself was being touched.
† Psychogenic defined as psychogenic pathway. Reflex defined as combined psychogenic and reflex pathway.
‡ Statistically significant.

Sexuality

In general all patients were happy to have sensations instead of being numb. Awareness of their penis contributed to their body image and they felt more complete (table 1). Twelve patients were more strongly aroused and masturbated more frequently, while 5 started masturbating for the first time postoperatively. During masturbation patients reported a significant increase in stiffness ($p = 0.008$) and satisfaction ($p = 0.016$) with their erections. For 8 patients it was easier to achieve an erection and orgasm while masturbating.

Many patients became more sexually active with a partner (frequency $p = 0.002$ and with more satisfaction $p = 0.039$). Three patients experienced orgasmic feelings for the first time. Eight patients felt the introduction of the penis into the vagina, which was new for them ($p = 0.008$). However, 1 patient reported decreased satisfaction in some situations as the new sensations did not meet his high expectations.

The semi-structured interview led to 3 items measuring satisfaction with sexuality, which showed increased satisfaction with their sex life in general ($p = 0.004$). (Cronbach's alpha for the satisfaction with sex scale was 0.78 before and 0.85 after the operation.) The 19 patients also scored significantly higher on the GAS ($p = 0.022$) after surgery, indicating better sexual functioning (table 1). On comparing the patients whose sensations matured to actual glans sensations to those whose sensations stayed in the groin, we noted that the first group was more easily aroused ($p = 0.013$), masturbated more frequently ($p = 0.013$) and was more satisfied with their sexuality (table 2).

Table 2. *Comparison of patients with glans sensation and groin sensation at second visit*

	Groin Sensation	Glans Sensation	p Value
Data from clinician			
No. pts	13	11	
No. SB/SCI	9/4	8/3	1.000
Level of lesion	L3 (T12-S1)	L4 (T12-L5)	0.976
Median mos since operations (range)	15 (12–22)	13 (11–24)	0.220
No. origin of erection (psychogenic/reflex)*	10/2†	4/7	0.036‡
Data from psychologist			
No. pts	8	10	
No. arousal:			
Strength of arousal (decreased/no change/increased)§	0/6/2	0/1/9	0.013‡
Erection during arousal (decreased/no change/increased)§	1/7/0	0/10/0	0.444
No. masturbation:			
Masturbation (no/yes)	2/6	0/10	0.183
Masturbation frequency/mo (decreased/no change/increased)§	0/6/2	0/1/9	0.013‡
Ease of erection (decreased/no change/increased)§	0/7/1	0/4/6	0.066
Ease of orgasm (decreased/no change/increased)§	0/6/2	1/4/5	0.342
Sensation of orgasm (decreased/no change/increased)§	0/6/2	1/3/6	0.153
Stiffness erection (VAS)	7.5 (4–10)	9 (8–10)	0.067
Satisfaction with sexuality:			
Satisfaction with erection during masturbation (VAS)	8 (0–10)	8 (7–10)	0.294
Satisfaction with sexual function (VAS)	5 (2–9)	8 (7–10)	0.027‡
Satisfaction with sexual life (VAS)	4.5 (1–9)	8 (3–10)	0.052
Satisfaction with sexual life in general (sum of 3 scores above)	17 (3–27)	24 (19–29)	0.055
Overall sexual functioning (GAS score)	36 (27–46)	31.50 (24–41)	0.196

* Psychogenic defined as psychogenic pathway. Reflex defined as combined psychogenic and reflex pathway.
† In 12 patients.
‡ Statistically significant.
§ Compared to preoperative status.

DISCUSSION

Using a new nerve rerouting procedure (TOMAX) we were able to restore unilateral glans penis sensation in 24 of 30 patients with spinal lesions. Sensation was restored on the operated side of the glans penis only due to the unilateral DNP anatomy.[18] The ilioinguinal nerve has a good cross-sectional caliber match with the DNP and the distal part of the DNP functions as a conduit for ingrowing axons of the ilioinguinal nerve. This axonal growth resulted in new penile sensations which developed in a sequence similar to that seen after traumatic nerve repair. The average amount of glans sensation obtained for 13 patients was 1.4 ± 1.47 gm, which was less than the preoperative donor groin sensation (0.78 ± 0.58 gm) and the glans sensation in 2 healthy populations (0.96 ± 0.15[12] and 0.83 ± 1.00 gm[9]). The differences are likely due to axonal loss at the nerve repair site and misdirection during regrowth.[19]

Patients experienced sensory changes from groin to glans with the development of pleasurable sensations. Patients who had glans sensations were more likely to gain erogenous benefits than those with sensations in the groin. These sensory changes could be attributed to brain plasticity. The human brain can adapt to new peripheral input but this depends on the pattern and frequency of use.[20] This might explain why glans sensations and beneficial erogenous sensations developed in all the sexually active patients. Their activities can be seen as sensory education programs in which visualization and motivation have major roles.[21,22] Although age is the most important factor in predicting sensory and functional recovery,[19,21,22] we found no differences related to age or the origin (SB or SCI) and level of the spinal lesion.

In 4 young patients with SB (age 13 and 14 years) we could not rule out that some postoperative changes might also be related to their increasing sexual awareness in puberty. However, several patients with SB preferred nerve transposition surgery before puberty to ensure the new sensations are incorporated and accepted as normal before sexual activity starts. Treatment might also contribute to a more effective sensory reeducation of the brain and make erogenous sensations even more likely.[22,23]

Psychologically the penis became a more real part of the body for most patients. Even the nonpainful, cold sensation with the introduction of a catheter contributed to the sense of being complete and less handicapped, which is important since most patients with SL use self-catheterization. Some patients became aware of urine passing through the urethra, which is hygienically and socially important.

Patients had more satisfaction with their erections during masturbation. The ability to have erections depends on preserving the psychogenic and/or reflex pathways of erectile function. Five patients with psychogenic-only pathways reported postoperatively that direct stimulation of the penis could induce erections and that these could be maintained more easily. The neurological bypass did not reconstruct the reflex arc S2–S4, so they are more likely sensory feedback enhanced (psychogenic) erections rather than real reflex erections, but they are still beneficial because maintaining erections is a recognized problem in patients with SL.[24]

With patients being more strongly aroused and more conscious of their new feelings, they masturbated more frequently and had more pleasurable sensations and sometimes orgasms. Five patients including 2 young patients with spina bifida masturbated for the first time ever, while 3 patients experienced their first orgasm. Patients were more confident in their sexual activities, aware of their partner touching the penis and able to appreciate the moment of intromission. This led to more frequent and more satisfying sexual activities, and a more open and meaningful sexual relationship.

Four patients with SCI had had sexual experiences before their trauma and 3 appreciated their improved situation. One sexually active patient with SCI was pleased with the results and experienced satisfaction comparable to that of his pre-trauma period. At his request, we are planning a similar procedure on the contralateral side to introduce sensation to the entire glans.

This study had several limitations such as the absence of a control group and the use of questionnaires/interviews to measure psychological function (although they were conducted by an independent psychologist). In addition, the sensory tests were performed only on the flaccid penis so the outcomes might have lower scores. Several patients reported more sensitivity of the glans in erections at home and some experienced glans instead of groin sensations.

We have started to perform this procedure in patients with similar pathology due to a persistent cauda equina syndrome and are now transposing the nerves bilaterally if BCR measurements are negative on both sides. In cases of positive BCR, end-to-side neurotization unilaterally or bilaterally could also be considered. In the future we plan to operate on patients with SB before puberty. Postoperative sensory education programs will be developed to make achieving erogenous sensation even more feasible.

The estimated incidence of SB is 1.9 per 10,000 newborns[25] and of SCI is 40 per million in the United States alone.[26] Thus, the new TOMAX procedure can be used to restore erogenous penile sensation and improve quality of life and sexual health in large numbers of patients. The procedure is straightforward, and can be performed by any surgeon trained in peripheral nerve surgery and microsurgery. Recently we introduced the technique in the United States resulting in the first 2 clinical cases outside the Netherlands.[27]

In conclusion, we show that restoring penile sensation can enhance sexual health and satisfaction in most male patients with a low spinal lesion. They felt more complete and less handicapped, discovered sexual activities for the first time or experienced them as more exciting and pleasurable. The development of a new reflex pathway in patients with solely psychogenic erections helped them gain and maintain more rigid erections. Improvements in managing urinary incontinence helped increase personal hygiene and independence and, thus, social participation. The TOMAX procedure should be offered to any patient with a spinal lesion with good sensation in the groin but no sensation in the glans, and it should become standard treatment for many patients in the future.

ACKNOWLEDGMENTS

J. L. Sandberg, psychologist trained in sexology, VUMC Amsterdam, The Netherlands, was involved in the preoperative and postoperative psychological evaluations, and was supported by the Johanna KinderFonds. J. L. Senior provided assistance and was supported by the Department of Plastic Surgery.

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