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REVIEW

What uro-gynecologists should know about sacral neuromodulation (SNM) for the treatment of refractory overactive bladder

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Abstract

Purpose To inform uro-gynecologists about the current standards and latest developments of sacral neuromodulation (SNM) in women with overactive bladder (OAB).

Methods Literature search in the PubMed database for articles published between 1988 and 2019 on SNM for OAB in women.

Results In total, 361 articles were identified and 51 articles retrieved for the review. SNM shows an objective success rate of 70–80%, OAB cure rate of 17–47% and a subjective satisfaction rate of 80–90%. These benefits have to be weighed against an adverse event rate of approx. 40%. SNM is significantly more successful than switching to another antimuscarinic after failed antimuscarinic drug therapy. Efficacy of SNM is slightly lower compared to bladder wall injections with 200 U botulinum toxin in the first months but efficacy of both treatments appears to be similar after 24 months. MRI examinations of patients with a sacral neurostimulator should only be performed after radiologist consultation. Sacral neurostimulators in patients with another pacemaker system should only be implanted after interdisciplinary consultation. The sacral neuromodulator should be turned off during pregnancy and delivery. SNM for OAB in patients with concomitant female sexual dysfunction or fecal incontinence seems to be beneficial.

Conclusions SNM is a successful and recommended second-line treatment of OAB. Sacral neurostimulators should preferably be implanted in SNM-centers because complications and the frequency of revisions are significantly reduced with increasing experience of the surgeon.

Keywords Overactive bladder · Urge incontinence · Implantable neurostimulators · Treatment efficacy · Postoperative complications

Introduction and purpose

The overactive bladder (OAB, urgency) syndrome is a gender unspecific clinical diagnosis which has been defined by the International Continence Society as urinary urgency, usually accompanied by increased daytime frequency and/or nocturia, with urinary incontinence (OAB-wet) or without (OAB-dry), in the absence of urinary tract infection or other detectable disease [1, 2]. OAB is highly prevalent with a population-based estimate of 13–36% in women [3]. OAB increases with aging and severity usually progresses over time [4]. OAB is not only a bothersome symptom syndrome, but also associated with a lower health-related quality of life, social isolation and a considerable morbidity such as falls and fractures, skin infections, functional impairment, anxiety and depression [5].

Treatment of OAB aims to reduce bothersome symptoms, restore quality of life and reduce morbidity. First-line treatment is non-surgical and consists of conservative (e.g., treatment of constipation, lifestyle interventions as well as behavioral and physical therapies) and pharmacological management (e.g., antimuscarinic drugs, β_3-adrenoceptor agonists), either alone or in combination [6–8]. In case of refractory OAB, surgery may be performed as second-line treatment which includes bladder wall injections of onabotulinumtoxinA (Botox®) or sacral neuromodulation (SNM).

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Uro-gynecologists frequently implement first-line treatments and botulinum toxin injections, but rarely perform SNM. This review article has the purpose to inform gynecologists about SNM in women and comprehensively describe the terminology, mechanism of action, implantation technique, efficacy, adverse events and special situations after the implantation.

Methods

A non-systematic literature review in the PubMed database for published articles between 1 Jan 1988 and 31 Dec 2018 was conducted to search for information on SNM in women. We used the search terms ["female" OR "women"] in combination with ["overactive bladder" OR "OAB"] OR ["urge incontinence" OR "urgency incontinence"] in combination with ["sacral neuromodulation" OR "sacral nerve stimulation" OR "SNM"] NOT ["percutaneous tibial nerve stimulation" OR "PTNS"]. The abstracts of the selected articles were then studied and relevant articles were selected for this analysis.

Results

In total, 384 articles were identified with the search strategy. Animal studies, double publications, studies with mixed female/male participants without clearly indicating gender specific data or articles without an abstract in English language were excluded ($n = 23$). After studying the abstracts, 51 articles were considered relevant for the purpose of this article. Additionally, the SNM operation room manual was used to describe the implantation technique [9] and eight articles were used to inform about OAB in general. Selected articles dealt with one of the following topics: terminology, mechanism of action, implantation technique, efficacy and adverse events, MRI examinations, cardiac pacemakers, female sexual dysfunction, pregnancy and childbirth as well as fecal incontinence.

Terminology of neuromodulation and mechanism of action

During electrical neuromodulation, nerves are stimulated to influence (modulate) organ function [10]. Neuromodulation techniques include SNM, pudendal nerve stimulation (PNS), percutaneous tibial nerve stimulation (PTNS), spinal cord stimulation (SCS) and deep brain stimulation (DBS). For the treatment of OAB, SNM or PTNS are used to treat the imbalance between urinary bladder stimulatory and inhibitory control systems by directly or indirectly influencing the function of afferent bladder nerves [11]. Current evidence based on both animal and human studies suggest that the mode of action of SNM is not merely the effect of electric pulses on the afferent sacral nerves S3 (S2–S4) affecting the end organs (e.g., bladder, rectum, pelvic floor) but to improve the central processing and reflex regulation in the urinary and bowel control systems. A joint mechanism of action for the treatment of OAB and fecal incontinence reflects expert opinion [12, 13]. In urodynamic studies of patients with OAB, SNM resulted in a significant increase of bladder volume at first uninhibited detrusor contraction, bladder volume at first desire to void, bladder volume at urgency, and maximum cystometric bladder capacity [14].

Implantation technique

SNM is performed in two stages [9, 15, 16]. During stage 1, a test electrode is percutaneously inserted uni- or bilaterally into the sacral foramen S3 (S2–S4) under general anesthesia or analgesic sedation without muscle relaxation (Fig. 1). The surgeon decides during the operation whether unilateral stimulation is sufficient or bilateral stimulation is necessary to anticipate functional bladder response. The correct position of the electrode is validated during the operation by X-ray imaging and testing of reflexes (e.g., plantar flexion of the ipsilateral great toe and anal sphincter contraction during stimulation of S3, Fig. 2). The electrodes are temporarily connected to an external electrical pulse generator (in case of unilateral foramen electrode placement) or two electrical pulse generators (in case of bipolar foramen electrode placement) at the end of the operation.

After the operation and during uni- and/or bilateral test stimulation (i.e., percutaneous nerve evaluation, PNE), the therapeutic effect on bladder function is tested over a period of 1–4 weeks [17]. However, latest studies have shown that the mean time to document PNE success may only be 3.3 days (range 1–9 days) [18]. Lower stimulation amplitude thresholds at the time of implantation and more active electrodes are associated with better long-term outcomes [19, 20]. Additionally, stronger plantar flexion of the ipsilateral great toe during intraoperative testing of the electrode seems to predict more durable SNM outcome and lower revision rates [21].

Stage 2 of the implantation is indicated when OAB (number of incontinence episodes or micturition frequency) has been reduced by at least 50% during PNE. Approximately 80% of patients with OAB have successful PNE [22, 23]. During stage 2 operation, a battery-powered implantable pulse generator (IPG), which is positioned in the fatty tissue of the gluteal region on the side of the electrode, is connected to the test electrode under general anesthesia or analgesic sedation (Fig. 3).

After successful implantation of the IPG and connection to the electrode(s), programming of the IPG is

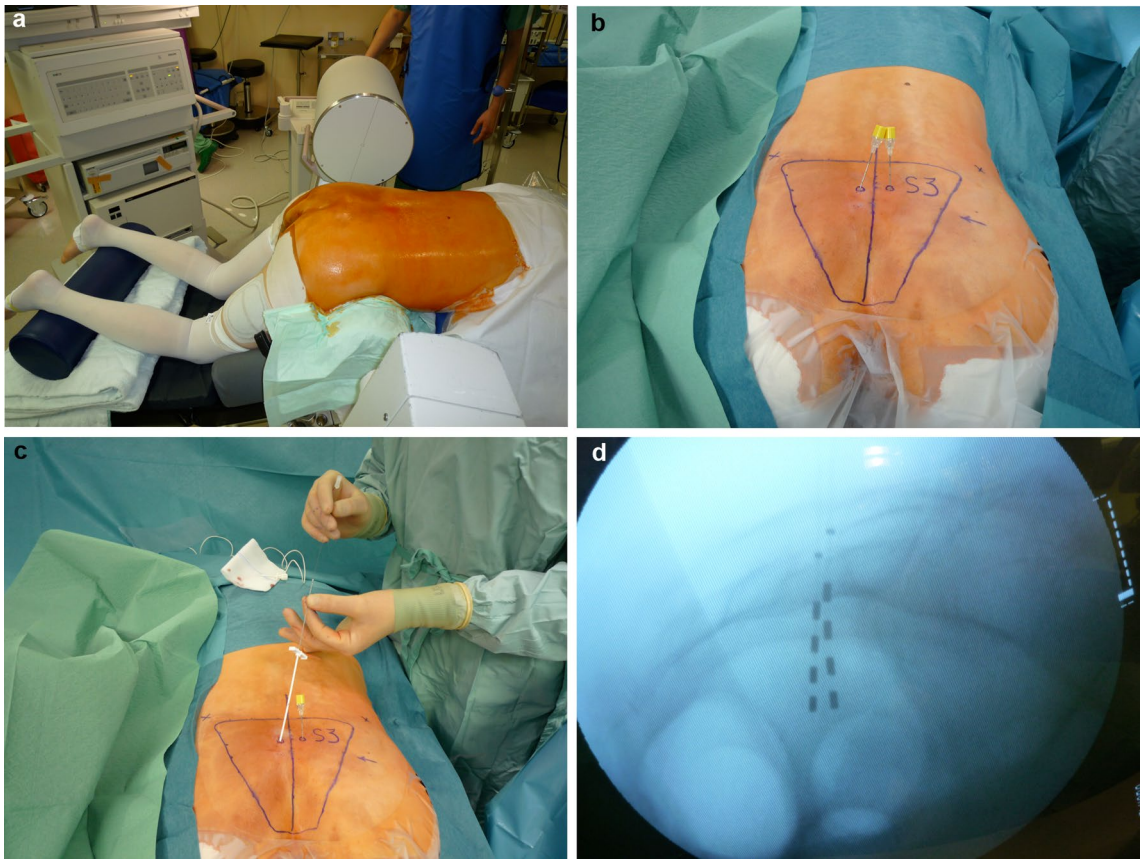

Fig. 1 **a** The patient is in prone position, legs abducted and moved downwards. The anus and feet have to be visible during the operation. The X-ray (C-arm) is already in the correct position. **b** After disinfection of the skin, the outline and the midline of the sacrum is marked with a blue pen. The S3 foramina are found 3 finger widths below the upper margin of the sacrum and 1 finger width lateral of the midline. Fluoroscopy in anterior–posterior direction can be used to identify the sacral foramina alternatively or additionally. Two foramen needles are already inserted into the S3 foramina. **c** After confirmation of the correct place of the foramen needles by X-ray and testing of the reflexes by applying electrical current to the electrodes (→Fig. 2), the foramen needles are replaced by tined-lead electrodes. **d** Confirmation of the correct depth of the tined-lead electrodes by X-ray. There are 4 radiopaque electrodes visible for electrical stimulation of different parts of the sacral nerve (source: private photo collection M. Oelke)

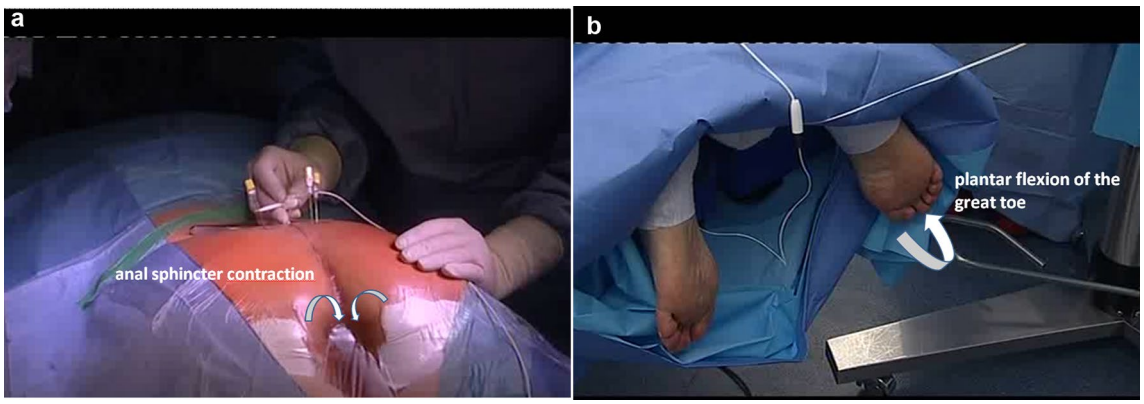

Fig. 2 Testing of the S3 reflexes by visualization of (**a**) anal sphincter contraction and (**b**) plantar flexion of the great toe on the side of the electrode (source: private photo collection C. Reisenauer)

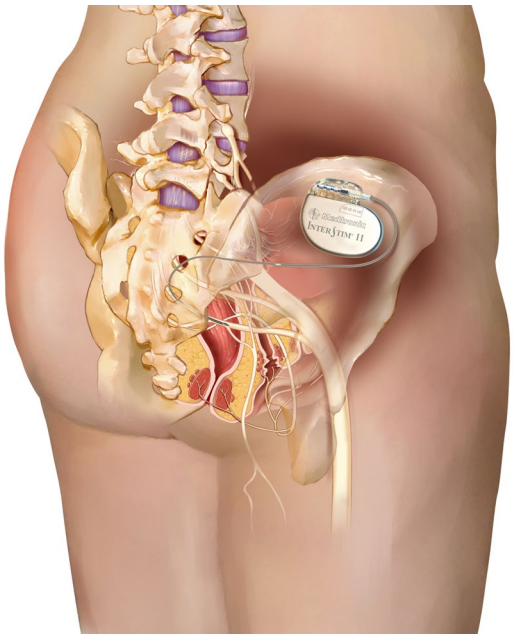

Fig. 3 Unilateral tined-lead electrode connected to the implantable pulse generator (InterStim® II) at the end of the second phase of the implantation. Uni- or bilateral stimulation of the sacral nerve S3 is used to modulate bladder function (source: Medtronic, Minneapolis, USA; with kind permission)

Fig. 4 External control unit to modify the electrical pulses of the implantable pulse generator (IPG). **a** Pre-programmed control unit to increase or decrease the electrical current of the IPG. **b** Most recent development of the external control unit (Smart Programmer®). The handset (white) is percutaneously positioned above the IPG which can be controlled or modified with a smartphone-like device (blue). Signals of the control unit are transmitted to the IPG via bluetooth technology (source: Medtronic, Minneapolis, USA; with kind permission)

necessary. Accordingly, the amplitude (0–10.5 V), pulse width (60–450 µs) and pulse frequency (2–130 Hz) of the electrical current can be programmed by the physician or health care professional with a percutaneously positioned control unit (Fig. 4). Patients can use the control unit for switching the IPG on, off, adjusting the amplitude of the electrical pulse or changing to predefined programs. In the on-mode, sacral nerves can be stimulated either continuously or intermittently under unipolar or bipolar stimulation. There are currently no clear guidelines for programming the bladder pacemaker, although some simple algorithms have been suggested [15, 24]. Adjustments usually have to be done for each patient on an individual level.

More than 300,000 sacral neurostimulators have been implanted worldwide so far (as of January 2019; data from the manufacturer, Medtronic, Minneapolis, USA) since the first report on SNM in 1990 [11]. CE mark certification (Europe) for the treatment of OAB has been available since 1994 and FDA approval (North America) since 1997. FDA approvals for additional indications such as non-obstructive urinary retention and fecal incontinence followed in 1999 and 2011, respectively.

The implantation technique has evolved over time. Initially, the IPG was implanted on the abdominal fascia of the lower abdomen on the side of the electrodes. In recent years, a smaller IPG (InterStim® II, Medtronic, Minneapolis, USA) is positioned in the ipsilateral fatty tissue of the gluteal region (Figs. 3 and 5). Significant progress was made in 2002 with the development of electrodes with small barbed hooks (so-called tined-lead electrodes), which are implanted during stage 1 for PNE and connected to the IPG in stage 2, without change of the electrode or electrode position (Fig. 6). This technique has improved the effectiveness of SNM [25] and reduced adverse events or revision operations [26]. Rechargeable pulse generators are currently being tested (r-SNM®, Axonics Modulation Technology Inc., Irvine, USA), which are smaller than conventional devices (approximately the size of a 2 Euro coin) and intended to significantly prolong the battery life

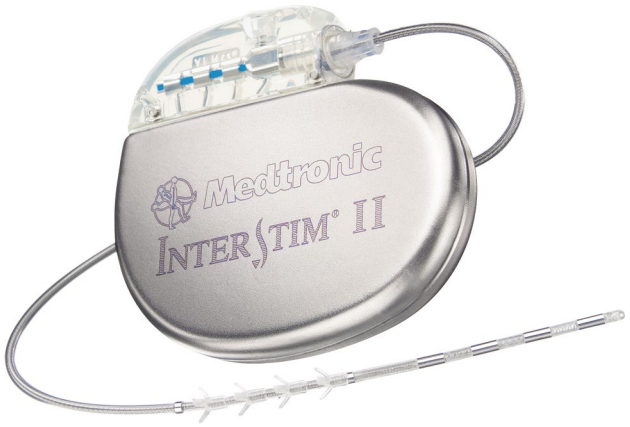

Fig. 5 Implantable pulse generator (IPG) with battery (InterStim II®) connected to a tined-lead electrode (source: Medtronic, Minneapolis, USA; with kind permission)

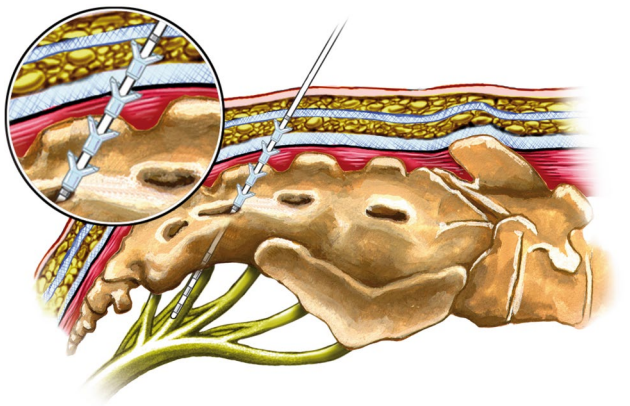

Fig. 6 Tined-lead electrode percutaneously inserted through the sacral foramen S3 and positioned close to the sacral nerve (source: Medtronic, Minneapolis, USA; with kind permission)

span of the InterStim™ unit from 5 to 7 years [27] to potentially 15 years [28].

Efficacy and side effects of SNM

SNM is considered a second line treatment of OAB. No studies on primary SNM (without prior conservative or pharmacological treatments) have been published so far. The efficacy and adverse events of SNM in the treatment of refractory OAB were assessed in systematic reviews [29–31], randomized controlled trials [22, 25, 32–36] and numerous uncontrolled studies. The majority of treated patients were women. Symptom reduction > 50% is achieved with SNM in approximately 70-80% of patients [37]. Normalization of symptoms (i.e., complete OAB recovery) was documented in approximately 39–47% of patients after 6 months [25, 32], 20% of patients with and 33% of patients without urinary incontinence after 4 years, and 17% after 10 years [37, 38].

In a prospective, monocentric trial of 272 patients, the success rate (reduction of symptoms > 50%) after successful PNE was 82% (95% confidence interval 76–88%) after 5 years according to per-protocol analysis [22]. The extent of symptom reduction depends on OAB baseline values. One study showed significant reduction of urgency incontinence from 3.1 to 1.0 episode per day [22], while another study documented a significant urgency incontinence reduction from 7.2 to 0.2 episodes per day [14]. In the same studies and patients, micturition frequency was significantly reduced from 12.6 to 7.2 voids per day [22], while micturition frequency was significantly reduced from 21.8 to 9.9 voids per day in the other study [14]. Study participants also reported a significant improvement in quality of life in all questions of the ICIQ–OAB–QoL questionnaire ($p < 0.0001$) [22]. Patients with SNM have been followed-up for up to 14 years (mean follow-up 50.7 months) in whom a long-term success rate of 84.8% for urgency incontinence was reported [26].

Complications after the implantation of the sacral electrodes and neurostimulator resulting in revision surgery vary greatly from 3 to 39% [26, 36]. Evolving implantation techniques, the learning curve of the surgeon, length of follow-up, including anticipated battery exchanges and salvage surgeries in case of loss of efficacy, can be the reason for the reported variances of revisions. In a retrospective monocentric case series of 59 patients, complications occurred in 25.4% of patients after a mean follow-up of 16.5 months; 8.5% of the patients had more than one complication, resulting in a total complication rate of 31% [39]. The most common complications were dislocation of the sacral electrode (13.8%), implant infection (most frequently with *Staphylococcus aureus*; 8.6%), wound healing disorders (5.2%), fibrosis along the electrodes (3.4%) and pain (1.7%). Long-term complications (5 years) occurred in up to 53% of patients, including adverse events which were resolved by conservative treatment [40]. Another study, also with a follow-up of 5 years, showed a similar frequency of complications; patients reported about a deterioration of effects leading to tined-lead revision surgery in 22%, pain in the area of the implant in 15% and loss of efficacy in 13% [22].

In summary, the frequency of complications, especially electrode dislocation, decreases with the electrode type (percutaneous tined-lead vs. fascia-anchored electrodes in older series), increasing experience of the surgeon with the implantation technique and better patient selection [39, 41].

Comparison of SNM with antimuscarinic drugs

In a randomized, controlled trial of patients with OAB who had been unsuccessfully treated with at least one oral antimuscarinic agent, the efficacy and adverse events of SNM

($n=70$) were compared with those of drug therapy with another antimuscarinic agent ($n=77$) that had previously not been used [25]. Treatment success after a follow-up of 6 months was significantly higher in patients with SNM than in patients with drug therapy (76% vs. 49%, $p=0.002$). Patients in the SNM group also reported about a significantly greater improvement in quality of life after 6 months (all parameters $p<0.001$), and significantly more patients in the SNM group reported about an improved or greatly improved reduction of lower urinary tract symptoms compared to antimuscarinic therapy (86% vs. 44%). The incidence of adverse events was similar in both groups (30.5% vs. 27.3%).

Comparison of SNM with botulinum toxin

In the ROSETTA study (Sacral Neuromodulation vs. Botulinum Toxin Assessment), the efficacy and adverse events of SNM ($n=189$) were compared with those of bladder wall injections with 200 units of onabotulinumtoxinA ($n=192$) in 386 women with urgency incontinence who had insufficient OAB improvement with antimuscarinic drugs [23]. During the first months of follow-up, the mean number of incontinence episodes was reduced slightly, although significantly better with botulinum toxin (-3.9 vs. -3.3 per day; mean difference 0.63; $p=0.01$). In the OAB questionnaire, women with botulinum toxin injections indicated significantly better results for symptom reduction (-46.7 vs. -38.6; mean difference 8.1; $p=0.002$), treatment satisfaction (67.7 vs. 59.8; mean difference 7.8; $p=0.01$) and treatment endorsement (78.1 vs. 67.6; mean difference 10.4; $p<0.001$). Although these differences were statistically significant, the authors concluded that they were not clinically relevant.

There were no significant differences at a follow-up of 6 months with regards to treatment convenience (67.6 vs. 70.2; mean difference -2.5; $p=0.36$), adverse events (88.4 vs. 85.1; mean difference 3.3; $p=0.22$) or treatment preference (92% vs. 89%; risk difference -3%; $p=0.49$). Urinary tract infections occurred significantly more frequently after botulinum toxin injections (35% vs. 11%; risk difference -23%; $p<0.001$). The need for bladder catheterization for the treatment of post-void residual urine or urinary retention in the botulinum toxin group was 8% after 1 month and 2% after 6 months. Revision surgery or explantation was performed in 3% of patients in the SNM group.

Results from the ROSETTA study with a 24-month follow-up were published only recently [36]. During follow-up, re-programming of the sacral neurostimulator was allowed in patients in the SNM group and re-injections (maximum two times, at least 6 months after the previous injections) in patients in the botulinum toxin group. A total of 70% of patients in the botulinum toxin group received a second treatment session (mean duration 385 ± 172 days after the first treatment) and 35% received a third session of injections (mean duration 290 ± 96 days after the second treatment). The majority of the significant differences between the treatment groups documented within the first 6 months were no longer detectable. Treatment equivalence was found for the disappearance of urgency incontinence, reduction in urgency incontinence episodes and response to the individual questions of the OAB questionnaire. Only data on treatment satisfaction and treatment endorsement remained significantly different and in favor of botulinum toxin injections until 24 months ($p<0.001$). Urinary tract infections occurred more frequently in the botulinum toxin group (24%) than in the SNM group (10%, $p<0.001$). In the botulinum toxin group, 6% of patients required intermittent catheterization after the second injection. In the SNM group, 3% of patients underwent revision surgery and 9% explantation of the sacral neurostimulator.

Special conditions during SNM

MRI examinations in patients with a sacral neurostimulator

The Interstim® II system was approved for MRI examinations of the skull and the brain under certain preconditions (1.5 Tesla, RF transmit/receive head coil). Off-label MRI studies of the abdomen, pelvis or spine with devices of 1.5 Tesla showed no adverse effects on the temperature or function of the sacral neurostimulator and, additionally, no impairment of MRI image interpretation [42, 43]. Furthermore, a recent study in eleven patients suggests that lumbosacral MRI examinations can be safely performed without significant adverse events or changes in impedances, battery life, sensory thresholds or therapeutic outcomes [44]. Nevertheless, MRI examinations below the skull should be avoided for the time being until all safety issues have been completely clarified. In cases of absolute indications or emergencies for MRI exams, an individual decision should be made together with the radiologist.

SNM in the presence of other pacemakers

The activated sacral neurostimulator can interfere with the function of other pacemakers (e.g., with cardiac pacemakers) [45]. When the electrical activity of the heart is diverted by surface electrodes, artefacts appear on the ECG pretending cardiac arrhythmia or atrial fibrillation. Therefore, cardiologists need to be informed of extra-cardiac neurostimulators. When programming or switching off the sacral neurostimulator, cardiac pacemakers from individual companies could also be re-programmed or switched off automatically. In three small case series with up to 5 patients, no interference (cross-talk) between cardiac pacemakers (without cardioversion and defibrillation function) and sacral neurostimulators

with continuous bipolar stimulation of the sacral nerve was detected [46, 47]. The authors concluded that SNM in the presence of cardiac pacemakers is safe. In general, a bipolar configuration is recommended for both the cardiac pacemaker as well as the sacral neurostimulator. To avoid any interference during programming, neurostimulators should be implanted with a minimum distance of at least 20 cm.

It remains unclear whether other modes of stimulation of the sacral neurostimulator or other types of cardiac pacemakers can still cause interference. Specialists for the other pacemaker system should, therefore, be consulted before the implantation of a sacral neurostimulator to clarify the compatibility of the pacemaker devices and also after the implantation/activation to confirm undisturbed pacemaker function. Even more careful consideration is required in patients with a sacral or spinal neuromodulator and an implantable cardioverter defibrillator device (ICD). Although a small study with three patients suggested that a dual-chamber or biventricular ICD can be safely used in patients with a previously implanted neuromodulator, ICD shocks could still cause temporary or permanent damage to the sacral neurostimulator [48].

SNM for female sexual dysfunction

Individual reports describe beneficial effects during SNM for the treatment of bladder dysfunction in women with treatment-resistant sexual arousal disorders, libido loss or lubrication disorders [49–51]. It remains unclear whether the improvement of bladder function or a direct effect on the pudendal nerve is responsible for the improved sexual function of women during SNM. Implantation of a sacral neurostimulator and SNM for the treatment of female sexual dysfunction has not been approved and, therefore, is currently only considered as a positive side effect during the SNM treatment of bladder dysfunction.

SNM during pregnancy and childbirth

No adverse effects on the fetus, mother or sacral neuromodulator have been described after using SNM during pregnancy [52]. Nevertheless, deactivation of the sacral neurostimulator during pregnancy is recommended because data is still sparse and no final consensus has been reached within expert groups. Caesarean section delivery to avoid damage to the implant should be discussed with the patients [53]. A national survey in France showed that 18.5% of patients switched off the sacral neurostimulator before pregnancy and the rest of the patients switched the device off during the first trimester [54]. When the neurostimulator was deactivated, urinary tract infections occurred frequently. Reprogramming of the sacral neurostimulator was necessary in about 20% of the patients after delivery due to reduced efficacy of SNM.

SNM in patients with OAB and simultaneous fecal incontinence

Fecal incontinence and/or chronic constipation can also be successfully treated with SNM. Whereas fecal incontinence is an approved and established indication for SNM, chronic constipation has to be categorized as experimental due to conflicting data [55]. Cure rates of isolated fecal incontinence during SNM, which are as high as 39% over a period of 5 years, appear to be even higher than those of urinary incontinence [38]. Case reports describe the successful treatment of fecal incontinence in about 50% of patients who had concomitant OAB [56, 57]. At present, however, it remains unclear to what extent SNM is suitable for the combined treatment of bladder and bowel dysfunctions since there are many etiologies and pathophysiologies of fecal incontinence or chronic constipation. Patients with combined urinary and fecal incontinence should, therefore, be discussed by an interdisciplinary team and treated individually.

Summary and conclusions

SNM is an effective treatment modality for OAB/detrusor overactivity with or without urinary incontinence, which, due to the invasiveness and necessity of anesthesia, is only indicated after treatment failure with conservative and/or pharmacological regimens (i.e., refractory OAB). The objective success rate of approx. 70–80%, OAB cure rate of 17–47% and a subjective satisfaction rate of 80–90% have to be weighed against revision rates of up to 40%. In addition, patients have to be counselled on the need for battery exchanges every 5–7 years.

In patients with refractory OAB, SNM is significantly more successful than switching to another antimuscarinic drug. Compared to bladder wall injections with 200 U botulinum toxin, the efficacy of SNM appears to be slightly lower within the first month. However, efficacy of both treatments is similar after a longer follow-up (24 months). It has to be taken into account that the recommended botulinum toxin dose is 100 U in patients with non-neurogenic bladder dysfunction and, therefore, the slightly but significantly higher efficacy for botulinum toxin within the first 6 months of treatment could also be caused by the higher botulinum toxin dose. Although the frequency of side effects appears to be similar, the type of side effects differs. Notably, urinary tract infections occur significantly more frequently after botulinum toxin injections. The advantages and disadvantages of SNM compared to botulinum toxin injections should be discussed

with patients with refractory OAB before the operation and a decision should be made on an individual basis. There is in general, no superiority of botulinum toxin over sacral neuromodulation (and vice versa) in terms of patient preferences. Outcomes in patient preference studies differ greatly since there is a significant disparity between the views of the clinicians and the patients [58–60]. During consultation, patients should be informed that botulinum toxin injections have to be repeated on a regular base, usually once per year, urinary tract infections may occur and patients need to be able and willing to catheterize themselves in case of large post-void residuals or urinary retention. Patients with SNM have to be informed that regular checks of the bladder and pacemaker functions and sometimes re-programming of the neurostimulator are necessary. Therefore, patients have to agree with follow-up visits and need to accept the complication and revision rates. SNM may be advantageous in OAB patients with concomitant detrusor underactivity (i.e., impaired detrusor contractility) and high post-void residuals because SNM is also indicated for non-obstructive urinary retention.

Some special situations need to be considered after implantation of the sacral neurostimulator. MRI examination caudal to the skull should not be performed in patients with a sacral neurostimulator or should only be performed for special indications and only after consultation with a radiologist. The sacral neurostimulator should be switched off before or during pregnancy and during childbirth. Patients with a sacral neurostimulator and another pacemaker system should be discussed and treated on an interdisciplinary basis, as interference between the pacemaker systems may occur and affect both pacemaker functions. In patients with OAB and a sacral neurostimulator, it has not yet been conclusively clarified whether sexual dysfunction or fecal incontinence ± chronic constipation can simultaneously be cured. Therefore, patients with simultaneous bladder and bowel dysfunction should be discussed by an interdisciplinary team and treated individually.

Taken together the wealth of data collected during the past 25 years, SNM is a valuable and successful second-line treatment of OAB. Uro-gynecologists should be familiar with SNM, although the majority will not perform the two stage implantation and SNM themselves. Patients should preferably be treated in SNM-centers because side effects and complications and, thus, the frequency of revisions are significantly reduced with the surgeon's experience.

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Compliance with ethical standards

Conflict of interest M Oelke has received for OAB a speaker honorarium from Astellas, Duchesnay, Pierre Fabre and Pfizer, is advisory board member of Astellas and Pfizer, received research grants from Astellas and Pfizer, and participated in clinical trials from Apogepha, Astellas and Pfizer. M Addali has no conflict of interest. C Reisenauer has received a speaker honorarium from Astellas, Boston Scientific, Coloplast and Medtronic.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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