Surveillance urodynamics for neurogenic lower urinary tract dysfunction: A systematic review

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Introduction: Baseline urodynamic characterization in patients with neurogenic lower urinary tract dysfunction (NLUTD) allows detection of unsafe storage and voiding pressures and optimization of these parameters through medical or surgical intervention. Surveillance urodynamics (sUDS) studies are performed in the ambulatory setting after baseline characterization, with the goal of monitoring bladder function. How often this study should be performed and the circumstances that should prompt repeated studies are unknown. The primary objective of this review is to evaluate the evidence supporting sUDS in the setting of NLUTD as assessed by whether the study leads to 1) change in patient management; 2) determination of new findings not suggested by imaging or symptoms; and 3) demonstration of superior outcomes compared to observation. The secondary objective is to review sUDS practice patterns among urologists in their assessment of NLUTD.

Methods: PubMed, EMBASE, and Cochrane Library databases were reviewed for English-language literature published between January 1975 and March 2018. Twenty-eight independent articles (1368 patients, 9486 patient-years of followup) were included. Given heterogeneous data, 49% of 263 subjects were asymptomatic, yet demonstrated sUDS abnormality prompting treatment.

Conclusions: Evidence supporting optimal surveillance for NLUTD is lacking. Level 2b–4 evidence suggests that sUDS is likely to modify patient treatment and often demonstrates findings that modify treatment in the absence of symptoms or imaging changes.
of the PubMed, EMBASE, and Cochrane Library databases for English-language literature published between January 1975 and March 2018. Medical subject heading (MeSH) terms included: 1) neurogenic lower urinary tract dysfunction; 2) neurogenic bladder; and 3) urodynamic(s). Each of these terms was crossed with: 1) long-term care; 2) long-term surveillance; and 3) long-term followup (Table 2). Only studies related to NLUTD and urological followup were included in this review article. Studies were also identified by hand search of reference lists and review articles.

Studies were included if they presented: 1) findings related to one of the four previously mentioned inquiries; 2) pediatric or adult data relating to sUDS; 3) published since 1975; and 4) written in English. sUDS was defined as ≥ 2 studies performed after baseline UDS characterization. We excluded review articles and studies not available in full-text format (Fig. 1). All articles were graded according to the Oxford Centre for Evidence-based Medicine guidelines.

Results

Initial records identified through database search included 659 articles; 31 additional records were identified through other sources. The study selection procedure is described in Fig. 1. During the data extraction process, articles were excluded if the detailed full review revealed that they did not meet the initial criteria and articles were added from the referenced bibliographies if they met the inclusion criteria. At the end of this full review, 28 of the 690 articles met our final criteria (Tables 3, 4).

All reviewed articles focused on NLUTD secondary to either spinal cord injury (SCI), multiple sclerosis (MS), or spina bifida. Results could not be combined due to heterogeneity of underlying pathology. sUDS was performed on a regular, specific interval (1–2 years) in nine studies and based on altered symptoms or imaging findings (recurrent urinary tract infection [UTI], increased incontinence between catheterization, or alarming features on ultrasound) in nine articles (predominantly MS). Individual findings for SCI, spina bifida, and MS patients are provided in the following sections.
Surveillance urodynamics for neurogenic lower urinary tract dysfunction

**SCI**

Five articles meeting level 4 evidence addressed sUDS in the SCI population (Table 3). Studies included 470 adults and 28 pediatric patients with 2393.4 and 107.3 patient-years of followup, respectively. Four of five articles performed sUDS based on regularly timed studies defined on a specific interval (1–2 years) while one article performed surveillance based on altered symptoms or imaging findings (recurrent UTI, increased incontinence between catheterization, or alarming features on ultrasound).

The impact of annual sUDS on adjustment of patient treatment was addressed by Linsemeyer et al.22 The authors performed a cross-sectional review of 96 individuals with stable traumatic SCI undergoing annual UDS evaluations. Changes in the urodynamic parameters and autonomic dysreflexia were determined by comparing the current study with the prior year. The main outcome measure was whether or not there was a need for intervention based on the UDS results. Overall, 47.9% of individuals required at least one type of intervention based on annual UDS: 82.6% were urological interventions (medication changes were most common, comprising 54.3% of urological interventions); 13.0% were non-urological interventions; and 4.3% were a combination of non-urological and urological interventions. The need for intervention was not influenced by the type of bladder management, the length of time post-injury, or level of injury. Only 5.2% of patients reported new-onset urological symptoms since their prior annual evaluation.

Nosseir et al23 also advised that reliance on clinical symptoms to prompt sUDS leads to failure to detect a large number of treatment failures in the SCI population. The authors reviewed 80 SCI patients with at least one followup visit per year for a minimum of five consecutive years. The focus was to determine how frequently the treatment regimen had to be modified due to annual sUDS results. Over a mean followup of 67.3 months, the treatment strategy had to be modified in almost all patients. If authors had relied solely on clinical symptoms or imaging findings, 68.75% of treatment failures would not have been detected.

Conversely, Edokpolol and colleagues24 established a safe lower urinary tract with baseline UDS, and subsequently performed annual renal ultrasonography for surveillance. sUDS was repeated only when patients presented with new symptoms or alarming radiological changes. Subjects were followed for a mean duration of 6.8 years. sUDS was repeated in 40% of subjects during the study period. After repeat sUDS for new onset of symptoms, bladder management was not changed in 64% cases. The dose or type of anticholinergic was increased or changed in 32% cases, and one subject received bladder augmentation. In four other subjects, the regimen was modified based on symptoms without repeating sUDS. Two new cases of pelvicaliectasis were present at the time of final ultrasound. One case was secondary to an obstructing stone and the second was due to refractory bladder pressures in a non-compliant patient. The authors concluded that an ultrasound-based surveillance approach is efficacious in SCI patients and suggest that annual sUDS may be unnecessary.

**Spina bifida**

Seven articles meeting level 2b–4 evidence addressed sUDS in the spina bifida population (Table 3). Studies included 120 adult and 587 pediatric patients with 1248 and 5208 patient-years of followup, respectively. Five of seven articles performed sUDS based on regularly timed studies defined on a specific interval (1–2 years) while two articles performed surveillance based on altered symptoms or imaging

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For the flow diagram of search strategy, please refer to the original document.
Table 3. Surveillance UDS in the setting of NLUTD

<table>
<thead>
<tr>
<th>Author</th>
<th>Pathology</th>
<th>No. of pts</th>
<th>Study type/quality</th>
<th>FU period (yrs)</th>
<th>UDS interval (yrs)</th>
<th>Regular or prompted by symptom</th>
<th>Percentage of studies that adjust treatment</th>
<th>Superior outcome compared to conservative management</th>
<th>New upper urinary tract deterioration</th>
<th>Percentage of studies that demonstrate sUDS change in asymptomatic pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linsenmeyer et al22</td>
<td>SCI</td>
<td>96</td>
<td>Level 4, cross-sectional</td>
<td>2</td>
<td>1</td>
<td>Regular</td>
<td>47.9% of studies prompt treatment change</td>
<td>No control group</td>
<td>None</td>
<td>43% of patients had asymptomatic sUDS deterioration (46-59.96)</td>
</tr>
<tr>
<td>Nosseir et al23</td>
<td>SCI</td>
<td>80</td>
<td>Level 4, retrospective cohort series</td>
<td>5</td>
<td>1</td>
<td>Regular</td>
<td>96% of patients underwent treatment change</td>
<td>No control group</td>
<td>None</td>
<td>69% of patients had asymptomatic sUDS deterioration</td>
</tr>
<tr>
<td>Schops et al24</td>
<td>SCI</td>
<td>246</td>
<td>Level 4, retrospective cohort series</td>
<td>6</td>
<td>6</td>
<td>Regular</td>
<td>40.6% of patients underwent treatment change</td>
<td>No control group</td>
<td>1% hydronephrosis, 5% low-grade reflux</td>
<td>Symptoms not tracked</td>
</tr>
<tr>
<td>Edokpolol et al25</td>
<td>SCI</td>
<td>48</td>
<td>Level 4, retrospective cohort series</td>
<td>6.8</td>
<td>Irregular</td>
<td>Symptom-based Treatment adjusted in 34%; in 10%, treatment changed for symptoms without repeating UDS</td>
<td>No control group</td>
<td>New hydronephrosis (2%)</td>
<td>sUDS performed only for symptomatic change</td>
<td></td>
</tr>
<tr>
<td>Chao et al26</td>
<td>SCI</td>
<td>28 ped</td>
<td>Level 4, retrospective cohort series</td>
<td>3.83</td>
<td>1–2</td>
<td>No control group</td>
<td>Symptoms not tracked</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarcan et al27</td>
<td>Regular</td>
<td></td>
<td>39% of patients underwent treatment change</td>
<td>No control group</td>
<td>None</td>
<td>Symptoms not tracked</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edelstein et al28</td>
<td>SB</td>
<td>25 ped</td>
<td>Level 4, retrospective cohort series</td>
<td>9.1</td>
<td>1</td>
<td>Regular yearly until toilet-trained, then symptom-based</td>
<td>32% of patients underwent treatment change</td>
<td>No control group</td>
<td>None</td>
<td>24% of children had asymptomatic UDS deterioration (6/25)</td>
</tr>
<tr>
<td>Spindel et al29</td>
<td>SB</td>
<td>148 ped</td>
<td>Level 2b, retrospective cohort series</td>
<td>4.5</td>
<td>1</td>
<td>Regular or when imaging revealed upper urinary tract changes</td>
<td>80% of patients in observation and 15% of patients in early intervention required treatment change</td>
<td>Less UUT deterioration in regular sUDS and intervention</td>
<td>UUT deterioration in 80% of patients in observation and 15% of intervention arm</td>
<td>Symptoms not tracked</td>
</tr>
<tr>
<td>Kaufman et al30</td>
<td>SB</td>
<td>214 ped</td>
<td>Level 4, retrospective cohort series</td>
<td>13</td>
<td>Irregular</td>
<td>Performed for imaging changes or incontinence at school age</td>
<td>37% of patients underwent treatment change</td>
<td>No control group</td>
<td>37% of patients had upper urinary tract deterioration</td>
<td>Symptoms not tracked; all 37% that required sUDS underwent this for imaging changes</td>
</tr>
<tr>
<td>Almodhen et al31</td>
<td>SB</td>
<td>37 ped</td>
<td>Level 4, retrospective cohort series</td>
<td>5</td>
<td>1</td>
<td>Regular</td>
<td>35% of patients had change to voiding pattern, CIC, or medication</td>
<td>No control group</td>
<td>8%, none post-puberty</td>
<td>Symptoms not tracked; 10% had imaging or renal scan changes</td>
</tr>
</tbody>
</table>

*Based on patients symptoms or sonographic findings (not regular intervals), CIC: clean intermittent catheterization; DESD: detrusor external sphincter dyssynergia; FU: follow-up; MS: multiple sclerosis; NLUTD: neurogenic lower urinary tract dysfunction; OR: odds ratio; ped: pediatric; SB: spina bifida; SCI: spinal cord injury; sUDS: surveillance urodynamics; UDS: urodynamic study; UUT: upper urinary tract; yrs: years.
Surveillance urodynamics for neurogenic lower urinary tract dysfunction findings (recurrent UTI, increased incontinence between catheterization, or alarming features on ultrasound).

**Table 3 (cont’d). Surveillance UDS in the setting of NLUTD**

<table>
<thead>
<tr>
<th>Author</th>
<th>Pathology</th>
<th>No. of pts</th>
<th>Study type / quality</th>
<th>FU period (yrs)</th>
<th>UDS interval (yrs)</th>
<th>Regular or prompted by symptom</th>
<th>Percentage of studies that adjust treatment</th>
<th>Superior outcome compared to conservative management</th>
<th>New upper urinary tract deterioration</th>
<th>Percentage of studies that demonstrate sUDS change in asymptomatic pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hopps et al31</td>
<td>SB</td>
<td>84 ped</td>
<td>Level 4, retrospective cohort series</td>
<td>10.4</td>
<td>Irregular</td>
<td>Based on imaging or symptom change</td>
<td>56% of patients underwent treatment change</td>
<td>No control group</td>
<td>Rarely (2/84) sUDS performed only for symptomatic change</td>
<td></td>
</tr>
<tr>
<td>Veenboer et al27</td>
<td>SB</td>
<td>120</td>
<td>Level 4, cross-sectional</td>
<td>10.4</td>
<td>Irregular</td>
<td>Based on imaging or symptom change</td>
<td>25.8% had unsafe bladder requiring treatment change</td>
<td>No control group</td>
<td>Not tracked OR of any sUDS abnormality given patient symptoms is 0.64</td>
<td></td>
</tr>
<tr>
<td>Ciancio et al32</td>
<td>MS</td>
<td>22</td>
<td>Level 4, retrospective cohort series</td>
<td>14</td>
<td>2.9</td>
<td>Symptom-based</td>
<td>55% of patients had a change to UDS pattern and all were offered treatment change</td>
<td>No control group</td>
<td>None</td>
<td>27% of patients had asymptomatic sUDS change</td>
</tr>
<tr>
<td>Wheeler et al34</td>
<td>MS</td>
<td>18</td>
<td>Level 4, retrospective cohort series</td>
<td>2.1</td>
<td>Symptom-based</td>
<td>55% of patients underwent treatment change</td>
<td>No control group</td>
<td>None</td>
<td>Prompted by changing or persistent symptoms</td>
<td></td>
</tr>
<tr>
<td>Blaivas et al36</td>
<td>MS</td>
<td>41</td>
<td>Level 4, retrospective cohort series</td>
<td>Variable</td>
<td>Irregular</td>
<td>Symptom-based</td>
<td>30% had changing UDS pattern or imaging change requiring treatment change</td>
<td>No control group</td>
<td>None</td>
<td>Bladder symptoms correlated poorly with any single urodynamic finding</td>
</tr>
<tr>
<td>Goldstein et al31</td>
<td>MS</td>
<td>9</td>
<td>Level 4, retrospective cohort series</td>
<td>Variable</td>
<td>Irregular</td>
<td>Symptom-based</td>
<td>44% had changing UDS pattern requiring treatment change</td>
<td>No control group</td>
<td>None</td>
<td>Prompted by changing or persistent symptoms</td>
</tr>
<tr>
<td>Schoenberg et al33</td>
<td>MS</td>
<td>33</td>
<td>Level 4, retrospective cohort series</td>
<td>2.5</td>
<td>Irregular</td>
<td>Symptom-based</td>
<td>36% had changing UDS pattern requiring treatment change</td>
<td>No control group</td>
<td>None</td>
<td>Prompted by changing or persistent symptoms</td>
</tr>
<tr>
<td>Bemelmans et al37</td>
<td>MS</td>
<td>40</td>
<td>Level 4, retrospective cohort series</td>
<td>2.5</td>
<td>Irregular</td>
<td>Single point</td>
<td>88% had UDS abnormality requiring treatment change</td>
<td>No control group</td>
<td>None</td>
<td>50% of asymptomatic patients had UDS abnormalities requiring treatment</td>
</tr>
</tbody>
</table>

*Based on patients symptoms or sonographic findings (not regular intervals), CIC: clean intermittent catheterization; DESD: detroseure external sphincter dyssynergia; FU: follow up; MS: multiple sclerosis; NLUTD: neurogenic lower urinary tract dysfunction; OR: odds ratio; ped: pediatric; SB: spina bifida; SCI: spinal cord injury; sUDS: surveillance urodynamics; UDS: urodynamic study; UUT: upper urinary tract; yrs: years.
and/or high filling or voiding pressures. Those at risk were either observed until radiological deterioration occurred, or were placed on prophylactic intermittent catheterization with or without anticholinergic medication based on annual sUDS. During the followup period, 80% of children in the observation group developed radiological evidence of UUT deterioration (inadequate bladder emptying, reflux, and/or hydronephrosis). In contrast, only 15% of children in the intervention group developed radiological evidence of UUT deterioration (inadequate bladder emptying, reflux, and/or hydronephrosis). Conversion from low- to high-risk occurred with new-onset hydronephrosis, febrile UTI, urinary retention, or incidental finding of VUR at the time of evaluation for continence. After a mean followup of 10.4 years, renal deterioration occurred in only one kidney of the high-risk group and one kidney in the group that converted from low- to high-risk, representing 5.36%; the remainder performed the study for symptomatic changes.

Controversy exists regarding the use of regularly scheduled sUDS compared to performing studies for symptomatic or radiological change. Kaufman et al\(^3\) reviewed 214 children presenting to a spina bifida clinic in a 13-year period. UDS were performed when UUTs deteriorated or in incontinent school-age children. On radiographic study, there was evidence of UUT deterioration in 79 children, including hydronephrosis in 34, hydronephrosis and vesicoureteral reflux (VUR) in 19, and reflux only in 26. Followup studies performed after clean intermittent catheterization and pharmacological therapy were instituted revealed resolution or improvement of UUT deterioration in 69%, while bladder compliance improved in only 42%. The results suggest that although radiological surveillance of patients with myelomeningocele allows recognition of UUT changes, the effects of elevated outlet resistance on bladder compliance are not as readily reversible as the initial radiographic findings.

Conversely, Hopps et al\(^3\) established a risk classification scheme to stratify the surveillance approach. High-risk patients underwent prompt UDS evaluation. Low-risk patients were followed closely at 2–4-month intervals with serial physical examination, UUT imaging, and urine culture. Conversion from low- to high-risk occurred with new-onset hydronephrosis, febrile UTI, urinary retention, or incidental finding of VUR at the time of evaluation for continence. After a mean followup of 10.4 years, renal deterioration occurred in only one kidney of the high-risk group and one kidney in the group that converted from low- to high-risk, representing 1.2% of all renal units.

Although controlled studies are currently lacking, use of symptom- or imaging-provoked sUDS in adult spina bifida patients may be beneficial. Veenboer et al\(^1^7\) performed a cross-sectional review of 120 adult spina bifida patients (median age 31.5 years) to determine characteristics associated with a hostile lower urinary tract on sUDS. In the multivariable model, unsafe bladder was significantly associated with being wheelchair-bound (odds ratio [OR] 5.36; p<0.008). Conversely, it was highly unlikely to find an unsafe bladder in asymptomatic patients that were not wheelchair-bound (negative predictive value 1.00). The authors concluded that if an adult patient with spinal dysraphism is not wheelchair-bound, unfavourable findings at sUDS are unlikely. If these patients are asymptomatic,

### Table 4. Practice patterns of surveillance UDS

<table>
<thead>
<tr>
<th>Author</th>
<th>Population</th>
<th>UDS strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elliott et al(^13)</td>
<td>Spina bifida</td>
<td>A survey was mailed to all 169 clinics listed by the Spina Bifida Association of America; 59% obtained routine UDS, commonly at intervals of 1–2 years</td>
</tr>
<tr>
<td>Veenboer et al(^17)</td>
<td>Spina bifida</td>
<td>A questionnaire was sent to all 365 urologists in the Netherlands regarding current assessment of adult spina bifida patients. Video UDS investigations (UDS) were performed on a regular basis (1–2 years) by 24.3%; the remainder performed the study for symptomatic changes</td>
</tr>
<tr>
<td>Blok et al(^32)</td>
<td>NLUTD</td>
<td>A questionnaire was mailed to members of the Canadian Urological Association; 75% of respondents undertook urodynamic study and 11% (n=9), video UDS; this was performed annually or every other year</td>
</tr>
<tr>
<td>Rikken et al(^36)</td>
<td>NLUTD</td>
<td>A questionnaire was mailed to 304 certified urologists of the Dutch Urological Association; 12% of respondents completed regular urodynamic studies every 1–2 years</td>
</tr>
<tr>
<td>Bycroft et al(^4)</td>
<td>SCI</td>
<td>12 Spine Injured Units in the U.K. and Eire were sent a questionnaire addressing basic practice relating to urological outpatient followup and UDS; Six units did not perform routine UDS; in four units that perform routine sUDS, range of frequency of UDS was from 1–3 years</td>
</tr>
<tr>
<td>Razdan et al(^33)</td>
<td>SCI</td>
<td>A mailed questionnaire was sent to the 269 American members of the Society for Urodynamics and Female Urology (SUFS); 85% of respondents performed surveillance video UDS every 1–2 years; the remaining 35% did not consider routine UDS needed and completed a cystogram if the patient had recurrent UTIs or deleterious upper urinary tract changes on US or other imaging study</td>
</tr>
<tr>
<td>Kitahara et al(^14)</td>
<td>SCI</td>
<td>A Japanese version of the 14-item questionnaire survey carried out in U.S. was mailed to 770 members of the Japanese Neurogenic Bladder Society (JNBS); cystometry was performed yearly by 174 (52.3%) respondents for the evaluation of vesicourethral function</td>
</tr>
<tr>
<td>Al Taweel et al(^31)</td>
<td>SCI</td>
<td>Questionnaire distributed to urologists working in Saudi Arabia and registered at the Saudi Medical Association; 62% repeat the study every year; the remaining 20% will do it every two years, and 12% will do it whenever the patients’ symptoms deteriorate</td>
</tr>
<tr>
<td>Cameron et al(^18)</td>
<td>SCI</td>
<td>Used a 5% Medicare sample to review data from over 7000 SCI patients. During the two-year period, 35.7% of patients saw a urologist and 6.7% had UDS</td>
</tr>
<tr>
<td>Welk et al(^19)</td>
<td>SCI</td>
<td>1551 SCI patients were followed for a median of five years after discharge from a rehabilitation hospital; the proportion of patients who had regular UDS at least once every two years was 10%</td>
</tr>
</tbody>
</table>

NLUTD: neurogenic lower urinary tract dysfunction; SCI: spinal cord injury; UDS: urodynamic study; UTI: urinary tract infection.
these findings are even more unlikely. In these patients, it is probably not necessary to perform routine UDS without symptoms or imaging prompting the study.

**MS**

Six articles addressed sUDS in the adult MS population (Table 3). Studies included 163 adults with 528 patient-years of followup. Five of six articles performed sUDS based on changing patient symptoms (recurrent UTI, increased incontinence between catheterization, or alarming features on ultrasound).

The changing clinical course of MS is a hallmark of the disease. Ciancio et al\(^\text{12}\) followed 22 adults with repeat UDS performed because of new or persistent LUTS. Overall, 55% of patients experienced a change in their urodynamic patterns and/or compliance during a mean followup of 42 months. In the largest retrospective series, Schoenberg and Gutrich\(^\text{13}\) performed repeated UDS evaluations on 33 symptomatic patients during a 2.5-year period and found differences in 12, all of whom changed from having detrusor hypocontractility to having detrusor hyperreflexia. Wheeler, Goldstein, and Blaivas et al\(^\text{34-36}\) also found temporal changes in the urodynamic patterns in the majority of patients.

Several authors have demonstrated poor correlation between UDS findings and patient symptoms in the MS population. Ciancio and colleagues\(^\text{12}\) found that 43% of MS patients with no urological symptoms developed a change in the urodynamic pattern and/or compliance on followup UDS evaluation. Similarly, in a prospective study by Bezemans et al\(^\text{17}\) 52% of patients demonstrated urodynamic abnormalities without symptoms. However, the incidence of positive urodynamic findings in patients with lower urinary tract complaints was 98%. The latter finding suggests that UDS evolution may be present without symptoms, but is highly likely if voiding symptoms exist.

Fortunately, the rate of UUT deterioration in MS with NLUTD is low. In a meta-analysis of 1882 patients with MS, only 1% demonstrated UUT tract abnormality.\(^\text{38}\) Fletcher et al\(^\text{19}\) investigated the prevalence of renal ultrasound abnormalities over time in MS patients with LUTS. The authors defined UUT damage as the presence of hydronephrosis, caliectasis, cortical scarring, or stone formation. Over a nine-year period, 173 patients had both UDS and renal ultrasound. Of these, 5.8% of subjects had abnormalities at initial ultrasound, whereas at followup, renal ultrasound (RUS) abnormalities were seen in 12.4% of patients. Overall, there were seven patients who developed new abnormalities. The authors concluded that the development of UUT abnormalities as determined by RUS overall is low, although older patients and those with abnormal compliance may merit closer supervision.

**Current practice patterns**

Eight cross-sectional studies (all level 3, four SCI, two NLUTD, two spina bifida) surveyed urologists regarding current practice patterns of sUDS in the setting of NLUTD (Table 4); 53% of 498 respondents and 39 specialty clinics in seven countries reported that they perform sUDS between 1–3 years using pooled estimate weighted average. The most common practice pattern was sUDS every 1–2 years.

These results were in contrast to two retrospective cohort series that demonstrated the actual use of sUDS among SCI patients was substantially less frequent than reported practice patterns suggest. Cameron et al\(^\text{18}\) observed a 6.7% use of sUDS in American SCI patients over a two-year period despite over 35% urological consultation in the same period. Similarly, Welk et al\(^\text{19}\) observed only 10% use of sUDS in Canadian SCI patients over a two-year period.

**Discussion**

**Change in patient management based on sUDS**

Table 3 demonstrates heterogeneous data (level 2b–4) with variable underlying pathology, variable stimulus for adjusting treatment, and variable conditions for prompting sUDS. Although pooled-estimate meta-analysis is not possible given heterogeneity, sUDS has a tendency to adjust patient treatment often. A weighted average of results demonstrated that surveillance adjusted treatment in 48.4% of patients.

**Determination of new findings in asymptomatic patients without imaging changes**

Similarly, clinical and methodologic heterogeneity of data limits the ability to perform pooled-estimate meta-analysis (Table 3) with respect to this question. Despite this, sUDS has a tendency to provide new findings that are not suggested by patient symptoms or imaging changes. A weighted average of results demonstrated that surveillance determined findings that prompted treatment in 48.9% of asymptomatic patients without imaging changes. However, after establishing a ‘safe’ lower urinary tract, prompting sUDS with imaging change or new symptoms did not appear to be associated with adverse outcomes in the short-term.\(^\text{23}\)

**Does sUDS demonstrate superior outcomes compared to long-term followup without UDS?**

There are currently no high-quality studies available to support or refute this premise. Available evidence is primarily level 4 without control groups. A single level 2b study is available within the pediatric population.
What are the current sUDS practice patterns among urologists in their assessment of NLUTD?

The most common self-reported practice pattern of sUDS in the management of NLUTD is every 1–2 years. Within the U.S. and Canada, healthcare utilization data suggests that the actual rate of sUDS in the neurogenic population ranges from 6.7–10%. The difference between self-reported practice patterns and actual use highlights the need for consensus in surveillance standards.

Conclusion

Available evidence supporting optimal surveillance protocols for NLUTD is lacking. Qualitative findings from level 2b–4 evidence suggest that sUDS is likely to modify patient treatment, and often leads to new findings not suggested by physical examination, imaging findings, or new patients symptoms. Establishing a risk-benefit ratio of these findings is not possible due to lack of control groups. There is currently no evidence that demonstrates regularly scheduled sUDS has superior outcome compared to sUDS performed for symptom or imaging change.

The most common practice pattern of surveyed urologists was to repeat sUDS every 1–2 years. Review of currently available guidelines (Table 1) demonstrated two conventional approaches for UDS. The primary approach is to stratify into risk groups with baseline UDS. Low-risk groups are those that have safe storage parameters, including high capacity, high compliance, and low storage pressure. High-risk groups include parameters that place UUT at risk, including detrusor-sphincter dyssynergia with sustained raised vesicle pressure or low compliance, before and after a change in bladder management; onset of UTIs or urinary tract stones; or presence of VUR or high post-void residual. sUDS is typically reduced in the former to a lengthy interval (although no consensus exists to define this interval). The latter group is typically investigated and followed at a more closely defined and regimented schedule, such as regular sUDS every 1–2 years.

An alternative to this approach is to establish a baseline with UDS followed by on-demand sUDS if patient presentation evolves during the course of followup. Findings such as new-onset hydronephrosis, reflux, deterioration in renal function, increased infection frequency, or urinary calculi formation prompt sUDS evaluation.

The optimal sUDS strategy in surveillance of NLUTD has not yet been established and will likely require further data to establish a validated protocol. This review demonstrated that existing literature is limited by small enrollment studies with heterogeneous populations completed over a time course that is extensive. There is clearly a need for further high-quality studies to determine the optimal surveillance strategy of UDS with NLUTD.
Surveillance urodynamics for neurogenic lower urinary tract dysfunction


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141