Learning curve for detection of pelvic parts of ureters by transvaginal sonography: feasibility study

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KEYWORDS: deep infiltrating endometriosis; DIE; LC-CUSUM; learning curve; transvaginal ultrasonography; ureter

CONTRIBUTION

What are the novel findings of this work?
Sonographers and/or gynecologists who are familiar with gynecological transvaginal sonography (TVS) should be able to become proficient in identifying the pelvic parts of both ureters after 40–50 TVS examinations.

What are the clinical implications of this work?
Detection of ureters is a feasible part of the TVS workup of women attending a tertiary referral center clinic. In deep infiltrating endometriosis, identification of ureters and diagnosis of proximal hydronephrosis can be vital to the woman and in the planning of surgery to prevent hydronephrosis and silent loss of kidney.

ABSTRACT

Objective To investigate how many examinations it takes to be able to identify the pelvic parts of the ureters on transvaginal sonography (TVS).

Methods This was a prospective study including consecutive women attending a gynecological outpatient clinic in a tertiary referral setting. Prior to commencement of the study, three trainees, with a focus on gynecological surgery and TVS but with no experience in identifying ureters, each observed an expert examiner performing 10 routine TVS examinations, including identification of both ureters. All were standardized gynecological TVS examinations, with visualization of the pelvic part of both ureters. Consecutive women were then examined, first by the expert, unobserved by the trainees, and then by one of the three trainees, in the presence of the expert. To ensure that identification of the pelvic parts of the ureters could be incorporated feasibly into routine gynecological TVS in a tertiary referral setting, a time limit of 150 s was set for successful identification of each ureter. A successful examination was defined by identifying both ureters within the time limit. The number of women examined by each trainee was determined by how quickly they achieved proficiency, which was evaluated using the learning curve cumulative summation (LC-CUSUM) score.

Results Between January 2017 and June 2017, a total of 140 women were recruited for the study, with 135 patients being included in the final analysis. The three trainees were able to identify the right ureter after a maximum of 48 (range, 34–48) TVS examinations, and the left ureter after a maximum of 47 (range, 27–47) TVS examinations.

Conclusions Sonographers and/or gynecologists who are familiar with gynecological TVS should be able to become proficient in identifying both ureters after 40–50 TVS examinations. Detection of the ureters is a feasible part of the TVS workup of patients attending a clinic in a tertiary referral center.

INTRODUCTION

Urinary tract endometriosis (UTE) affecting the ureters or urinary bladder occurs with a prevalence of 1–5.5% in women affected by endometriosis1 and is associated with more advanced stages of deep infiltrating endometriosis (DIE)2,3. Ureteral involvement and thereby ureteral obstruction may lead to hydronephrosis and parenchymal damage4,5. The challenge with UTE and secondary...
obstruction is that symptoms are often non-specific; for example, dysmenorrhea and pelvic pain, which occur in 39–79% and 37–64% of cases, respectively\textsuperscript{2}. Only 69% of patients with bladder endometriosis exhibit urinary complaints\textsuperscript{1}.

Ureteral endometriosis is associated with retrocervical as well as rectosigmoidal DIE\textsuperscript{6}; its prevalence varies from 4.4% to 21% in these cases. In retrocervical DIE, ureteral endometriosis is particularly associated with lesions > 3 cm in diameter\textsuperscript{1,7,8}. Surgical treatment of UTE is regarded as a safe procedure in expert hands, with low major-complication rates if performed in a tertiary referral setting\textsuperscript{9,10}. Accurate presurgical staging of DIE is of paramount importance in order to counsel patients adequately and to plan the surgical procedure with a multidisciplinary team. Transvaginal sonography (TVS) can be used to diagnose the anatomical location of a ureteral lesion, as well as its size and distance from the ureteral orifices. It is possible with TVS to diagnose proximal hydronephrosis up to the level of the uterine artery. Several studies have described identification of the pelvic part of the ureter on TVS and proposed that assessment of the ureters should be part of the TVS examination in women with suspected DIE\textsuperscript{11–13}. Furthermore, TVS has been demonstrated to allow visualization of early stages of ureteral obstruction, even prior to sonographic detection of renal hydronephrosis\textsuperscript{14}.

The learning process of trainees, with regard to the number of examinations necessary to obtain competence, can be assessed by the learning curve cumulative summation (LC-CUSUM) test\textsuperscript{15–17}. LC-CUSUM has been used previously to evaluate the use of TVS in endometriosis\textsuperscript{18–22}. The aim of the present study was to evaluate the learning curve for TVS-based detection of the pelvic parts of the ureters in a tertiary referral setting.

**METHODS**

In this prospective study we recruited consecutive women attending an outpatient gynecological clinic in a tertiary referral center for endometriosis and pelvic pain (Hospital St John of God, Vienna, Austria) between January 2017 and June 2017. The number recruited was dependent on how many were required for the trainees to reach proficiency. We excluded women who were virgins and those with previous hysterectomy or surgery for DIE, including bowel, bladder or ureteral resection and/or urinary tract procedures. The local institutional review board approved the study (Hospital St John of God Ethics Committee Meeting number 117) and informed consent was obtained from all participants.

The sonographers participating in the study were an expert examiner (G.H.) and three trainees (M.K.A.-E., C.R., U.S.), who were general gynecologists with a basic knowledge of TVS but without experience in TVS for detecting the pelvic parts of ureters. They had completed their gynecological training over the previous 12 months, and had each performed approximately 1000 TVS examinations. Prior to commencement of the study, each trainee observed 10 routine TVS examinations, including scanning of the ureters, performed by the expert.

TVS scans were carried out following a standardized procedure and using a Voluson E8 or E10 ultrasound machine (GE Healthcare, Zipf, Austria), equipped with a 7.5-MHz transvaginal probe. First, visualization of the proximal part of both ureters up to the crossing of the uterine arteries was attempted. The uterus, ovaries, bladder and bowel were examined according to the International Deep Endometriosis Analysis (IDEA) proposal for documentation of DIE\textsuperscript{12}. The urinary bladder and urethra were then identified in a longitudinal, mid-sagittal section. This point in time was defined as Time 1. The transvaginal probe was then retracted slightly and moved towards the lateral pelvic wall to identify the distal, intramural part of the ureter, including the ureteral orifice in proximity to the bladder trigone (Figure 1). The ureter was then followed up to the crossing of the uterine arteries and common iliac vessels, which were visualized using Doppler sonography. This point in time was defined as Time 2. The time needed for identification of the pelvic parts of the ureters was calculated as Time 2 minus Time 1, as described by Pateman et al.\textsuperscript{11,23}. The ureteral diameter for both sides was then measured at rest, i.e. in the absence of peristalsis, and during dilatation.

**Figure 1** Transvaginal ultrasound images of right (a) and left (b) ureters (\textsuperscript{**}}, ureterine artery (\textsuperscript{**}) and bladder apex (\textsuperscript{*}).
Each woman was examined first by the expert and then by one of the three trainees. The trainees were not present during the initial, expert examination. This examination included inspection, bimanual palpation and the TVS examination. The woman’s clinical history and symptoms were also recorded. One of the three trainees then repeated the TVS examination in the presence of the expert. In case of discrepancy or if the trainee did not visualize both ureters successfully, the woman was re-examined by the expert in the presence of the trainee and the results were explained, in order to enhance the trainee’s diagnostic skills. The main outcome measure was the correlation of detection at TVS of both ureters by Trainee 1, 2 or 3, compared with the gold standard expert examination. A time limit of 150 s for identification of each ureter was set in order to evaluate the feasibility of including this examination step in clinical practice and workup protocols; any examination taking longer than this was counted as a failure.

Statistical analysis

Analysis was performed using the SPSS statistical package, version 22 (IBM Corp., Armonk, NY, USA). Continuous variables are expressed as median and interquartile range and categorical variables as frequency and percentage.

In order to examine the learning curve, i.e. to assess the number of TVS examinations needed to be capable of detecting the pelvic parts of the ureters, we used the statistical tool LC-CUSUM. This method was designed to indicate when a process has reached a predefined level of performance. By evaluating the number of sequential interventions of successes and failures, the test allows monitoring of individual performance during the learning process of new methodologies and techniques. The null hypothesis (H0, performance is inadequate) is continuously tested against the alternative hypothesis (H1, performance is adequate). A score is computed from successive outcomes, with successes yielding negative scores and failures yielding positive scores, as previously reported by Tammaa et al.19. At the point at which the score reaches a predefined limit, h, the test rejects the null hypothesis in favor of the alternative, and performance is deemed adequate. LC-CUSUM values are plotted on the y-axis and the number of examinations is plotted on the x-axis. The following parameters were applied to this series: P0 = 0.175 as an unacceptable failure rate and P1 = 0.1 as an acceptable failure rate. We chose a control limit of h = 1.25.

RESULTS

From January 2017 until June 2017 we recruited 140 women. One woman was excluded due to virginity, two because of a history of hysterectomy and two due to prior surgery for UTE; of these, one had pain during examination and preferred not to undergo a further examination by a trainee. Thus, 135 patients were included in the final analysis; their demographic characteristics are given in Table 1. None of these women experienced severe pain during TVS, so no examinations were interrupted for that reason. There were no cases of proximal hydroureter detected. The LC-CUSUM plot showed that Trainees 1, 2 and 3 reached the predefined level of proficiency for identification of the right ureter after 48, 34 and 38 patients, respectively (Figure 2a). The trainees were proficient in identifying the left ureter after 47, 38 and 27 patients, respectively (Figure 2b).

Table 1 Demographic data and ultrasound findings of 135 women undergoing transvaginal sonography for detection of pelvic parts of ureters

| Characteristic                      | n (%) or mean ± SD |
|-------------------------------------|--------------------|
| Age (years)                         | 36 ± 11            |
| Gravidity                           |                    |
| 0                                   | 38 (28)            |
| 1–4                                 | 57 (42)            |
| Hormonal therapy                    |                    |
| 0                                   | 45 (33)            |
| 1–4                                 | 77 (57)            |
| Dysmenorrhea                         |                    |
| 0                                   | 2 (1)              |
| 1–4                                 | 17 (13)            |
| Dyspareunia                         |                    |
| 0                                   | 12 (9)             |
| 1–4                                 | 2 (1)              |
| Dysuria                             |                    |
| 0                                   | 16 (12)            |
| 1–4                                 | 4 (3)              |
| Uterosacral ligaments               |                    |
| 0                                   | 16 (12)            |
| Bowel                               |                    |
| 0                                   | 1 (1)              |
| Bladder                             |                    |
| 0                                   | 10 (8)             |
| 1–4                                 | 13 (10)            |
| Vagina/rectovaginal septum          |                    |
| 0                                   | 1 (1)              |
| 1–4                                 | 12 (9)             |

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Figure 2 LC-CUSUM test scores for transvaginal ultrasound identification of pelvic parts of right (a) and left (b) ureters by three trainees. If score is under decision limit (solid gray line), trainee is not considered proficient. If score is above decision limit, trainee is considered proficient to identify pelvic parts of ureter. Trainee 1, -----; Trainee 2, ---; Trainee 3, ----.
TVS visualization of endometriomas, we also observed a non-specific symptom, but can confer significant morbidity due to renal damage if left undiagnosed and untreated. Diagnosis of the condition at an early stage may therefore be capable of identifying the right and left ureters ranged between 34 and 48 scans and between 27 and 47 scans, respectively. Moreover, the choice of 1.25 as the predefined LC-CUSUM score cut-off was confirmed as a suitable threshold for defining that proficiency had been reached in TVS identification of the pelvic parts of the ureters. Table 2 presents the time required to identify right and left ureters and their diameter measurements at rest and during dilatation according to the expert and Trainees 1–3.

### DISCUSSION

UTE affecting the ureters is rare and often with non-specific symptoms, but can confer significant morbidity due to renal damage if left undiagnosed and untreated. Diagnosis of the condition at an early stage may therefore reduce morbidity rates. TVS is a valuable, non-invasive and low-cost tool with which the ureters can be identified as part of routine gynecological TVS examination. Leading experts have suggested that TVS of the bladder and ureters should be included as part of the diagnostic workup of women with suspected endometriosis. Tammaa et al. demonstrated that the learning curve for detection of the uterorectal sliding sign and the presence of rectal DIE using TVS requires around 40 TVS examinations for proficiency to be reached. Using the same approach, in the present study we have demonstrated similar results regarding visualization of normal ureters by TVS. The trainees, with a basic level of competence in TVS, acquired an adequate level of proficiency in identifying the right ureter after a maximum of 48 TVS examinations, and the left ureter after a maximum of 47 TVS examinations. In accordance with the results of Bazot et al., who evaluated learning curves for TVS visualization of endometriomas, we also observed a certain degree of intertrainee variability, with the number of scans required to reach proficiency for the right ureter ranging between 34 and 48 scans, while that for the left ureter ranged between 27 and 47 scans. This may be explained by small differences in the experience of the trainees as well as technical aspects. Nevertheless, the number of scans (about 48) apparently required in order to become capable in identifying the ureters should be easily incorporated into training protocols for TVS and feasible in everyday clinical teaching practice.

There are some limitations of this study. Eligible women were recruited from a tertiary referral setting, in which gynecologists perform both the TVS workup and surgery. Thus, the learning curve may be different for trainees in other settings, in which these disciplines are separate. All three trainees were general gynecologists with basic experience in TVS. Therefore, our results may not be transferable to gynecological residents or less experienced gynecological staff performing TVS without any prior knowledge. Finally, the time limit of 150 s to identify successfully each ureter may have been too low. However, it was set to assess the practical feasibility of including examination of the ureters as part of the routine TVS workup in a tertiary referral setting. Finally, we cannot exclude small differences regarding the individual teaching experience; the interaction between expert examiner, patient and trainee may have differed from day to day, thereby influencing the learning curves.

In conclusion, the present study is the first to show that performing around 40–50 TVS examinations is necessary to become capable of identifying, using TVS, the pelvic part of the ureters in a tertiary referral setting. Identification of the ureters could be included in the workup of all patients with pelvic pain. Implementation of this diagnostic step may enhance the detection rates of early ureteral obstruction.

### Table 2 Time to identify successfully pelvic parts of right and left ureters, and ureteral size at rest and at dilatation, on transvaginal ultrasound, for expert examiner and Trainees 1, 2 and 3

| Examiner          | Ureter side | Time (s) | Diameter of ureter (mm) | At rest | At dilatation |
|-------------------|-------------|----------|-------------------------|---------|---------------|
| Patients of Trainee 1 | Right       | Expert 4 (3–5) [1–16] | 2.4 (2.0–2.9) [1.5–3.8] | 2.8 (2.5–3.7) [2.3–4.7] |
|                   | Left        | Expert 4 (3–5) [2–41] | 2.3 (2.1–2.8) [1.5–6.5] | 2.9 (2.4–3.6) [1.6–6.7] |
|                   | Right       | Trainee 1 Right 22.5 [6–38.8] [3–53] | 2.1 (1.9–2.5) [14–40] | 3.0 (2.7–3.4) [2.0–5.2] |
|                   | Left        | Trainee 1 Left 18.5 (12.5–31) [4–70] | 2.3 (1.8–2.4) [1.6–3.4] | 3.1 (2.5–3.5) [2.3–5.9] |
| Patients of Trainee 2 | Right       | Expert 5 (3–6) [2–17] | 2.4 (2.3–2.5) [1.5–4.2] | 2.8 (2.5–3.6) [2.1–4.4] |
|                   | Left        | Expert 4 (3–5) [2–9] | 2.3 (2.2–2.4) [1.5–3.4] | 2.6 (2.5–3.2) [1.9–4.4] |
|                   | Right       | Trainee 2 Right 12 [7–19] [2–90] | 2.4 (2.1–2.7) [1.7–4.1] | 3.1 (2.6–4.0) [2.0–5.3] |
|                   | Left        | Trainee 2 Left 12 [8–20] [2–80] | 2.3 (1.8–3.0) [1.2–3.5] | 3.1 (2.6–4.1) [1.9–5.5] |
| Patients of Trainee 3 | Right       | Expert 4 (3–6.5) [1–20] | 2.3 (2.0–2.8) [1.6–3.6] | 3.1 (2.6–3.6) [2.0–4.7] |
|                   | Left        | Expert 4 (2–7) [1–55] | 2.4 (1.9–2.7) [0.9–3.7] | 2.9 (2.5–3.3) [1.3–4.5] |
|                   | Right       | Trainee 3 Right 10.5 (5–28.5) [3–59] | 2.1 (1.7–2.6) [1.0–4.2] | 2.9 (2.3–3.3) [1.5–5.0] |
|                   | Left        | Trainee 3 Left 10.5 (5–24.5) [1–59] | 2.1 (1.7–2.6) [1.4–3.9] | 2.6 (2.3–3.0) [1.4–4.5] |

Data are presented as median (interquartile range) [range]. Examinations exceeding the time limit of 150 s were considered as failures and not included.
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Curva de aprendizaje para la detección de las partes pélvicas de los uréteres mediante ecografía transvaginal: estudio de viabilidad

RESUMEN

Objetivo Investigar cuántos exámenes se necesitan para poder identificar las partes pélvicas de los uréteres en la ecografía transvaginal (ETV).

Métodos Se trata de un estudio prospectivo que incluyó a mujeres que acudieron consecutivamente a una clínica ginecológica ambulatoria en un entorno de especialistas terciarios. Antes de comenzar el estudio, tres pasantes con interés en la cirugía ginecológica y la ETV pero sin experiencia en la identificación de uréteres, observaron respectivamente a un examinador con experiencia mientras realizaba 10 exámenes rutinarios de ETV, incluida la identificación de ambos uréteres. Todos eran exámenes ginecológicos estandarizados por ETV, con visualización de la parte pélvica de ambos uréteres. A continuación, las mujeres fueron examinadas en orden consecutivo, primero por el experto, sin ser observadas por los aprendices, y luego por uno de los tres aprendices, en presencia del experto. Para asegurar que la identificación de las partes pélvicas de los uréteres se pudiera incorporar de manera factible a la ETV ginecológica rutinaria en un entorno de especialistas terciarios, se fijó un plazo de 150 segundos para la identificación satisfactoria de cada uréter. El éxito del examen se definió mediante la identificación de ambos uréteres dentro del plazo establecido. El número de mujeres examinadas por cada aprendiz se determinó por la rapidez con que alcanzaron la competencia, que se evaluó utilizando la puntuación de la suma acumulativa de la curva de aprendizaje (LC-CUSUM, por sus siglas en inglés).

Resultados Entre enero y junio de 2017, se reclutó un total de 140 mujeres para el estudio, y 135 de ellas se incluyeron en el análisis final. Los tres aprendices pudieron identificar el uréter derecho después de un máximo de 48 (rango, 34–48) exámenes de ETV, y el uréter izquierdo después de un máximo de 47 (rango, 27–47) exámenes de ETV.

Conclusiones Los ecografistas y/o ginecólogos que están familiarizados con la ETV ginecológica deberían ser capaces de llegar a ser competentes en la identificación de ambos uréteres después de 40–50 exámenes de ETV. La detección de los uréteres es una parte factible de la ETV de los pacientes que acuden a una clínica en un centro de especialistas terciario.

通过经阴道超声检查探测输尿管盆腔部位的学习曲线：可行性研究

摘要

目的 通过经阴道超声检查（TVS）识别出输尿管盆腔部位。

方法 本研究是一项前瞻性研究，涉及在三级转诊背景下有女性患者连续不断就诊的一家妇科门诊。在本研究开始之前，已对妇科手术和TVS为重（但并无识别输尿管经验）的三名实习生，各自观摩了一位专家进行10次常规TVS检查，其中包括对双侧输尿管的识别。所有检查均为标准妇科TVS检查，包含双侧输尿管盆腔部位可视化，女性患者连续不断地接受检查，首先由专家检查，实习生在旁观摩，然后在专家面前，由三名实习生中的一名实施检查。为确保在三级转诊背景下可识别到输尿管盆腔部位可吸入常规妇科TVS检查中，我们把150秒设定为成功识别双侧输尿管的时限。我们将一次成功的检查定义为在有限内识别出双侧输尿管。结果实习生检查女性患者的人数是根据实习生快速操作的程度来决定的，这个程度则是采用学习曲线累积合计（LC-CUSUM）评分进行评估的。

结果 在2017年1月至6月之间，总共为该研究征募到140名女性，有135名患者被包含到最终分析中去。三名实习生能够在最多48次（范围为34–48次）TVS检查中识别出右侧输尿管，并在最多47次（范围为27–47次）TVS检查中识别出左侧输尿管。

结论 熟悉妇科TVS的超声波检查医师和/或妇科医生应该能够在40–50次TVS检查后熟练识别双侧输尿管。培训输尿管是患者在前往三级转诊中心门诊接受TVS病情检查时切实可行的一部分。