CT Three-Dimensional Visualization Model in Diagnosis and Treatment of Stress Urinary Incontinence: A Retrospective Study

Xiaoxiang Jin, Haibin Tang, and Gang Chen

OBJECTIVE
To study the clinical effect of stress urinary incontinence sling surgery based on CT 3-dimensional visualization model, and to explore the value of three-dimensional visualization model in the diagnosis and treatment of stress urinary incontinence.

METHODS
Patients with stress urinary incontinence in our center from October 2020 to March 2022 were studied retrospectively. Among them, 16 cases received preoperative 3-dimensional visualization model construction, 18 cases did not use preoperative 3-dimensional model construction. The perioperative results, the postoperative results and the correlation between some related parameters of 3-dimensional visualization model and the severity of stress urinary incontinence were analyzed.

RESULTS
Compared with traditional surgery, the operation time of 3D group is significantly shorter (P < 0.05). There was no significant difference in intraoperative blood loss, perioperative fever, bleeding, micturition, pudendal or inguinal pain and postoperative symptom improvement. The posterior vesicourethral angle measured by 3-dimensional reconstruction model was correlated with ICI-Q-SF score.

CONCLUSIONS
The construction of three-dimensional visualization model of stress urinary incontinence can be used in clinic as a safe and effective new preoperative evaluation technique, and more potential applications can be further explored.

Stress urinary incontinence refers to the involuntary leakage of urine from the urethral orifice when abdominal pressure increases, such as sneezing, coughing, laughing or exercise, and the urodynamic examination showed that during filling bladder manometry, involuntary urine leakage occurred in the case of increased abdominal pressure without detrusor contraction, which is the most common type of urinary incontinence in women.1-3 Obesity, pregnancy and delivery are generally considered to be the main risk factors for stress urinary incontinence.4 According to the literature, about 25-45% of the women in the world have varying degrees of stress urinary incontinence, among which the prevalence rate of 40-59 years old is the highest.3,5,6 Stress urinary incontinence affects the patients’ daily activities, normal work and social interaction, seriously reduces the quality of life, and its severity is significantly related to the degree of anxiety and depression of the patients. If left untreated, the symptoms may be further aggravated. It has caused a huge medical and economic burden on the society.7-9

There are a variety of treatment methods for stress urinary incontinence. At present, the treatment is mainly divided into conservative treatment and surgical treatment. Conservative treatment mainly includes behavioral therapy, pelvic floor muscle training, drug therapy, electrical stimulation therapy and electromagnetic therapy.10,11 It is considered to be the first choice for the treatment of stress urinary incontinence because of its high safety and few complications.10 Surgical treatment can be performed for patients with poor effectiveness of conservative treatment, and the goal of surgery is to restore the normal anatomy and function of the pelvic structure.12 Common surgical procedures include middle urethral sling, vaginal suspension, autologous fascia sling and para-urethral injection of fillers.11,13

Visual 3D reconstruction technology has been widely used in hepatobiliary surgery, neurosurgery, urology and...
other surgical fields. In the field of urology, the key to the accurate completion of the operation is to master the anatomical structure of the kidney, ureter, bladder, and blood vessels before operation. A 3-dimensional space model can be constructed from the original imaging data of patients by visual 3D reconstruction technology. It can improve the accuracy of medical diagnosis and treatment planning. It has important clinical value in guiding operation process, improving operation efficiency, shortening operation time, reducing unnecessary exposure and intraoperative bleeding, avoiding intraoperative injury and reducing operative complications.

At present, the application of three-dimensional visualization model is mainly focused on kidney, ureter and bladder-related diseases, but rarely mentioned in urine control. This article intends to make a retrospective study to compare the clinical effects of stress urinary incontinence sling surgery based on three-dimensional visualization model and traditional stress urinary incontinence, and to explore the value of three-dimensional visualization model in the diagnosis and treatment of stress urinary incontinence.

MATERIALS AND METHODS

Inclusion and Exclusion Criteria

Inclusion Criteria. The diagnosis of stress urinary incontinence is considered by clinical symptoms, signs and related auxiliary examination. There is no obvious surgical contraindication in preoperative examination. Transvaginal tension-free urethral suspension was performed in our hospital. Patients who have completed the construction of 3D visualization models are included in the 3D group. The rest of the patients were included in the normal group.

Exclusion Criteria. Transvaginal tension-free urethral suspension was not performed in our hospital; follow-up data was incomplete or missing; patients who have had a prior history of transvaginal slings.

Procedure

In the 3D group, the CTU examination was performed before operation, and the imaging data were constructed by 3-dimensional visualization technology. The surgeon determined the puncture angle according to the 3-dimensional visualization model before operation, and evaluated whether there were important muscles, variant blood vessels and other tissues on the puncture route. During the operation, the patient took the lithotomy position to expose the anterior vaginal wall. At about 1 cm from the urethral orifice, a longitudinal incision with a long 1.5 cm was taken and separated to both sides of the vagina, and the tissue were separated to the inferior ramus of pubis by scissors. Fix the Solyx polypropylene sling at the anchor end of the puncture device, pierce the closed hole along the tissue channel, and release the puncture device. In the same way, pass the other end of the sling through the obturator. In this process, our common experience is to operate close to the inferior ramus of pubis and penetrate to the inner upper edge of the obturator to avoid injury to the main obturator arteriovenous trunk and nerves pierced from the lateral superior edge of the obturator. Then adjust the sling straight and place it in the middle of the urethra without tension. Except for no preoperative 3D visualization model, the operation in the normal group was the same as that in the 3D group.

Observation Index

Perioperative Index. Operation time, intraoperative blood loss, postoperative bleeding, fever, inguinal pain.

Follow-up Index. Voiding at 1 and 6 months after operation, inguinal pain, and ICI-Q-SF score at 6 months after operation. If the score of life impact is less than 3, the operation is considered to be successful.

Acquisition of Parameters from 3D Visualization Model

In the 3D visualization model software, the quartile window mode is selected to transparent other organs and tissues in the 3D view, leaving only the urethra and bladder. Using 3-dimensional angle measurement tool, referring to 2-dimensional coronal plane, sagittal plane and transverse section, the angle between urethral axis and posterior wall of bladder was measured as the posterior vesicourethral angle (Supplementary Fig. 1. A, B, C, D).

Statistical Processing

Using SPSS25.0 statistical software for statistical analysis. Statistical analysis was performed with the independent-samples t-test, Mann-Whitney U test or Wilcoxon for continuous variables, and the χ2 test or Fisher’s exact test for categorical variables. Shapiro-Wilk test is used for normal distribution, and Pearson correlation analysis is used for correlation analysis of normal distribution. A P value less than 0.05 was considered to indicate statistical significance.

RESULTS

General Information

A total of 34 patients with stress urinary incontinence who met the inclusion and exclusion criteria in the Department of Urology of the first affiliated Hospital of Chongqing Medical University from October 2020 to March 2022 were collected. There was no significant difference in preoperative data such as age and BMI between the two groups (P > 0.05), as shown in Table 1.

Surgery Related Information

All patients underwent transvaginal tension-free urethral suspension performed by the same surgeon. The difference of the operation time (min) between the normal group and the 3D group [47.5(41.25, 53.75) vs 60(50, 74.75), Z = −2.378, P = 0.017] was statistically significant (P < 0.05), which suggested the use of 3D visualization model may shorten the operation time. There was no difference between the normal group and the 3D group in intraoperative bleeding, as shown in Table 2.

Perioperative and Follow-up Complications

There were no differences between the normal group and the 3D group in the postoperative fever [1(6.3%) vs 1(5.6%), P = 1.00], the postoperative bleeding [2(12.5%) vs 4(22.2%), P = 0.66] and the postoperative inguinal pain [6(37.5%) vs 6(33.3%), χ2 = 0.064, P = 0.80]. And there were no differences between the two groups in inguinal pain at the time of 1-month follow-up [3(18.8%) vs 2(11.1%), P = 0.648] and 6-month follow-up [3 (18.8%) vs 2(11.1), P = 0.648], as shown in Table 3.

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Change of ICI-Q-SF Score
The differences of the ICI-Q-SF score before and after the operation were statistically significant (\(P < 0.05\)) in 3D group [18 (17,19) vs 0(0,4), \(Z = 3.536, P < 0.001\)] and normal group [18 (17,19) vs. 0(0,7.2), \(Z=-3.628, P < 0.001\)], which suggested the operations of both groups were effective, as shown in Supplementary Table 1.

Success Rate of Operation
There was no difference between the two groups in the success rate of operation [15(93.8%) vs 14(77.8%), \(P = 0.34\)], as shown in Supplementary Table 2.

Analysis of Correlation
In 3D group, the posterior vesicourethral angle was positively correlated with ICI-Q-SF score \((r = 0.742, P < 0.001)\), which indicated that excessive posterior vesicourethral angle was related to high ICI-Q-SF score, as shown in Supplementary Table 3.

Comment
The high prevalence rate of stress urinary incontinence and its impact on quality of life gradually make it one of the diseases that could not be ignored in urology. At present, the gold standard surgery of the disease is transvaginal tension-free urethral suspension, However, due to local anatomical factors, small operation space and important tissues in pelvic, it is difficult to learn the operation and is prone to related intraoperative and postoperative complications.

Nowadays, 3D reconstruction technology has been widely valued and applied. Through the 3D reconstruction software, the digital model of the patient can be established on the personal computer, the reasonable operation plan can be worked out, and the operation rehearsal based on the individual characteristics of the patient can be realized. By using the reconstructed 3-dimensional digital model of renal artery, kidney and tumor, Ukimura et al accurately found the branches of

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Table 1. General information of patients

<table>
<thead>
<tr>
<th></th>
<th>3D Group (n = 16)</th>
<th>Normal Group (n = 18)</th>
<th>Statistical Value</th>
<th>(P) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>51.0 ± 7.80</td>
<td>53.5 ± 8.13</td>
<td>-0.912</td>
<td>0.369*</td>
</tr>
<tr>
<td>BMI/kg/m²</td>
<td>24.2 ± 2.65</td>
<td>25.0 ± 2.76</td>
<td>-0.858</td>
<td>0.397*</td>
</tr>
<tr>
<td>ALPP/cmH₂O</td>
<td>81.1 ± 27.1</td>
<td>65.3 ± 24.1</td>
<td>1.799</td>
<td>0.081*</td>
</tr>
<tr>
<td>ICI-Q-SF score</td>
<td>17.7 ± 2.06</td>
<td>18.1 ± 1.71</td>
<td>-0.655</td>
<td>0.517*</td>
</tr>
<tr>
<td>Complications†</td>
<td></td>
<td></td>
<td></td>
<td>0.681†</td>
</tr>
<tr>
<td>positive</td>
<td>4(25)</td>
<td>3(16.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>negative</td>
<td>12(75)</td>
<td>15(83.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Menstrual history</td>
<td></td>
<td></td>
<td>0.216</td>
<td>0.642†</td>
</tr>
<tr>
<td>Menopausal</td>
<td>11(68.8)</td>
<td>11(61.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Premenopausal</td>
<td>5(31.2)</td>
<td>7(38.9)</td>
<td></td>
<td></td>
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<tr>
<td>gynecological surgery</td>
<td></td>
<td></td>
<td></td>
<td>0.18†</td>
</tr>
<tr>
<td>positive</td>
<td>1(6.3)</td>
<td>5(27.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>negative</td>
<td>15(93.7)</td>
<td>13(72.2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values are given as mean ± standard deviation or n (%).
* Independent-samples t-test.
† Complication refers to patients with basic diseases such as hypertension, diabetes, coronary heart disease, etc.
§ Fisher’s exact test.
² \(\chi^2\) test.

Table 2. Comparison of intraoperative index

<table>
<thead>
<tr>
<th></th>
<th>3D Group (n = 16)</th>
<th>Normal Group (n = 18)</th>
<th>Z Value</th>
<th>(P) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation time/min</td>
<td>47.5 (41.25, 53.75)</td>
<td>60 (50, 74.75)</td>
<td>-2.378</td>
<td>0.017</td>
</tr>
<tr>
<td>Blood loss/ml</td>
<td>20 (6.25, 30)</td>
<td>20 (10, 50)</td>
<td>-0.445</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Values are given as median (\(P_{25}, P_{75}\)).
Mann-Whitney U test.

Table 3. Comparison of perioperative and follow-up complications

<table>
<thead>
<tr>
<th></th>
<th>Perioperative</th>
<th>1-Month Follow-up</th>
<th>6-Month Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3D Group (n = 16)</td>
<td>Normal Group (n = 18)</td>
<td>(\chi^2) Value</td>
</tr>
<tr>
<td>fever</td>
<td>1(6.3)</td>
<td>1(5.6)</td>
<td>1.00*</td>
</tr>
<tr>
<td>bleeding</td>
<td>2(12.5)</td>
<td>4(22.2)</td>
<td>0.66*</td>
</tr>
<tr>
<td>inguinal pain</td>
<td>6(37.5)</td>
<td>6(33.3)</td>
<td>0.064</td>
</tr>
</tbody>
</table>

Values are given as n (%).
* Fisher’s exact test.
† \(\chi^2\) test.
tumor-specific arteries through detailed preoperative planning and intraoperative navigation, and successfully realized "zero ischemia" partial nephrectomy. It has also been reported that the digital three-dimensional model of renal calculi can provide reliable and comprehensive guidance for surgical design, and the preoperative virtual simulation operation has important guiding significance for improving the lithotripsy rate and reducing operative complications. A number of studies have confirmed that the digital model can help doctors simulate surgery before operation, make preoperative planning, avoid blood vessels that may be accidentally injured during operation, accurately find the operation area, improve the success rate of operation and reduce the risk of operation. But this technology is rarely used in the therapy of stress urinary incontinence. Therefore, we suggested patients to perform CTU before urinary incontinence sling surgery, and tried to use 3-dimensional visualization model technology to reconstruct the surgical area.

The model can clearly show the important structures of the pelvic floor and the position relationship, including the angle between urethra and bladder, the shape of the main obturator artery and vein trunks, and whether there are large vascular branches in the path of separation or puncture. If there were no large vessels in the path of separation or puncture, we can separate quickly and safely choose the puncture angle close to the inferior ramus of the pubis to puncture, so as to increase the speed of operation and reduce the risk of operation. If there were large blood vessels in the path of separation or puncture, we would know before the surgery by the 3D model, and we would be more careful in the process of separation and puncture to avoid bleeding caused by injury. Thanks to this, we have made a personalized operation plan for each patient before operation, so that the surgeon has a clear idea of what they he should notice in the surgery. From our results, there is no statistical difference in the safety and effectiveness of the operation between the 3D group and the normal group, which indicates that this operation, like the traditional operation, can be used as an option for surgical treatment. In terms of operation time, the 3D group is shorter than the normal group. According to our analysis, its advantage is to make the surgeon familiar with the specific structure of the area before operation, which can shorten the operation time. The amount of bleeding and postoperative complications in the 3D group in this study were not significantly different from those in the normal group. According to our analysis, the reason may be that the surgeon in this study has a high degree of mastery of the operation, and he can also complete the operation well without the construction of a preoperative model, so there may be a certain bias. This is also an area worthy of improvement in this study.

After further exploration of the model, we found that the parameters of the model can be used to predict the severity of the patient’s condition. From our results, we can see that the posterior vesicourethral angle is related to the high ICI-Q-SF score. We found that this kind of parameters have been widely used in ultrasound, such as the area of pelvic floor hiatus, the distance from bladder neck to the inferior edge of pubic symphysis and so on. These parameters are often used to judge the injury of pelvic floor function in patients with stress urinary incontinence, and can be used as an effective index to evaluate the effect of rehabilitation treatment of stress urinary incontinence. And the price of ultrasound is low, which makes it easier for patients to accept. However, the imaging effect of ultrasound is limited by the proficiency of ultrasound doctors, so the accuracy of parameters often varies. The price of CT 3D reconstruction is expensive, and there are some rays, but the parameters obtained are objective data, and the accuracy is guaranteed. Therefore, the two methods can be considered to complement each other clinically and choose according to the specific situation.

This study has the following limitations: 1) The study is a retrospective study, the sample size is small, the follow-up time is short, and the results may be biased, so it is necessary to increase the sample size and carry out prospective studies; 2) The study is not blinded, which may cause certain bias; 3) CT 3-dimensional reconstruction model has further value in diagnosis and prognosis. This study only discussed the posterior vesicourethral angle, and more parameters can be further explored in the future.
CONFLICT OF INTEREST
No Conflict or indicate specific conflict.

Acknowledgments. None.

SUPPLEMENTARY MATERIALS
Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.urology.2022.11.015.

References