Title
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Author(s)
Nishimoto, Ken-ichi; Tashiro, Koichiro; Yoshida, Naomasa; Harimoto, Koji; Nishikawa, Keiichiro; Tanaka, Tomoaki; Nakatani, Tatsuya; Yasuda, Kosaku

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STUDY ON THE RELATION OF THE SHAPE OF THE UROFLOWMETROGRAM AND THE URETHRAL LOSS COEFFICIENT CALCULATED FROM THE UROFLOWMETROGRAM

Ken-ichi NISHIMOTO1, Koichiro TASHIRO1, Naomasa YOSHIDA1, Koji HARIMOTO1, Keiichiro NISHIKAWA1, Tomoaki TANAKA2, Tatsuya NAKATANI2 and Kosaku YASUDA3

1The Department of Urology, Fuchu Hospital,
2The Department of Urology, Osaka City University, Graduate School of Medicine,
3The Department of Urology, Dokkyo University, School of Medicine, Koshigaya Hospital

The shape of the uroflowmetrogram reflects voiding conditions. Using a voiding simulation, we examined whether the urethral loss coefficient (LC) calculated from the approximated uroflowmetrogram correlates with parameters that regulate the shape of the uroflowmetrogram.

A total of 161 normal and abnormal uroflowmetograms were used. Normal female subjects and patients before and after transurethral resection of the prostate (TURP) were also studied. The ratio of maximum flow rate (Qmax) to flow time (T), a parameter expressing the shape of the uroflowmetrogram, was calculated. The uroflowmetograms were approximated using a voiding model, and the urethral LC was calculated.

As a result, a strong negative correlation was observed between the Qmax-flow time ratio, Qmax/T, and LC. Qmax/T is the vertical to horizontal ratio of the uroflowmetrogram and indicates the average degree of acceleration of flow rate during voiding. On the other hand, urethral LC, which can be estimated from the shape of the uroflowmetrogram, is considered a kind of urethral resistance. We concluded that when urethral resistance is high, the degree of acceleration of flow rate is low on average. Our study also indicated that Qmax/T was less affected by voided volume (VV) compared to Qmax. As Qmax/T is not as dependent on VV, it is useful for comparing cases with different VV.

Key words: Loss coefficient, Uroflowmetry, Voiding model, Maximum flow rate, Simulation

INTRODUCTION

The shapes of uroflowmetograms are thought to reflect voiding conditions. This is because the temporal change in flow rate is dependent on the relation of detrusor pressure and urethral resistance during voiding. We have reported a method to distinguish normal and abnormal uroflowmetograms using three parameters regulating the shapes of uroflowmetograms. Two of these parameters do not have dimensions while one (Qmax/T) does. This dimension is L^3T^-2 and is the same as the temporal change in flow rate.

On the other hand, the urethral loss coefficient (LC) can be calculated from the relation of kinetic energy and pressure loss obtained by approximating the uroflowmetograms using a voiding model. This LC is a kind of urethral resistance and is presumed to have a negative correlation with the degree of acceleration of flow rate. By comparison with the actually measured Qmax/T ratio, we can determine whether urethral LC can be practically used, whether it can be conveniently substituted by Qmax/T and to what extent Qmax/T reflects urethral LC. For this purpose, we examined the relation between urethral LC and the shape of the uroflowmetrogram.

MATERIALS AND METHOD

A total of 161 normal and abnormal uroflowmetograms were used. In addition, 9 normal female subjects and 16 cases before and after transurethral resection of the prostate (TURP) (8 patients) were studied. The Qmax/T ratio was calculated from maximum flow rate (Qmax) and flow time (T) obtained from these curves (Fig. 1). Uroflowmetograms were approximated using our...
previously reported voiding model\(^3\), and urethral LC and voided volume (VV) were calculated\(^5\). As the temporal change in pressure loss contributing to urethral inertial resistance, frictional resistance and elastic resistance can be separately calculated by approximating the uroflowmetograms using our voiding model\(^4\), LC was calculated as follows. When the integral value of pressure loss during voiding time contributing to inertial, frictional and elastic resistance was \(P_L\), \(P_R\) and \(P_C\), respectively (Fig. 2), and the total sum of energy used for elastic resistance during voiding was \(W_L\), \(LC = (P_R + P_C)/W_L\). VV was calculated by integrating the approximated flow rate. Age was not taken into consideration.

**RESULTS**

The relation of \(Q_{\text{max}}/T\) and LC was expressed by the regression line \(Q_{\text{max}}/T = 1.09 \times \text{LC}^{-0.54}\) (Fig. 3). The relation of \(Q_{\text{max}}\) and LC was similarly expressed by \(Q_{\text{max}} = 18.3 \times \text{LC}^{-0.56}\). When the contribution of VV on \(Q_{\text{max}}/T\) and \(Q_{\text{max}}\) was studied, the contribution rate of both LC and VV on \(Q_{\text{max}}/T\) calculated by multivariate analysis was \(R^2 = 0.55\). The contribution rate of both LC and VV on \(Q_{\text{max}}\) was \(R^2 = 0.67\).

**DISCUSSION**

Urethral LC had a negative correlation with \(Q_{\text{max}}/T\), and the contribution rate of LC alone on \(Q_{\text{max}}/T\) was 51% and the correlation coefficient was 0.71. The contribution rate of both VV and LC on \(Q_{\text{max}}/T\) was 55%. As there was only a 4% increase in the contribution rate when VV was taken into consideration, the effects of VV were thought to be minimal. The contribution rate of LC alone on \(Q_{\text{max}}\) was 36% and the correlation coefficient was 0.6. The contribution rate of both LC and VV on \(Q_{\text{max}}\) was 67%. This indicated that the degree of contribution of LC alone was smaller on \(Q_{\text{max}}\) compared to \(Q_{\text{max}}/T\), while the degree of contribution of both LC and VV was similar on \(Q_{\text{max}}\). These results suggested that \(Q_{\text{max}}/T\) better reflected urethral LC compared to \(Q_{\text{max}}\), and that the effects of VV were minimal on \(Q_{\text{max}}/T\). \(Q_{\text{max}}/T\) is therefore more suitable compared to \(Q_{\text{max}}\) when examining patients with different VV.

\(Q_{\text{max}}\) is often actually used in comparing the degree of changes in lower urinary tract obstruction, but as the degree of contribution of LC and VV on \(Q_{\text{max}}\) is about the same, \(Q_{\text{max}}\) is affected not by VV alone but also by LC to the same extent. When this relation is illustrated using a VV-\(Q_{\text{max}}\) nomogram, the relation of VV-\(Q_{\text{max}}\) is thought to change with urethral LC as a parameter\(^5\) (Fig. 4). That is, when VV is the same, \(Q_{\text{max}}\) increases as LC decreases and \(Q_{\text{max}}\) decreases as LC increases. This agrees with actual clinical phenomena.

![Fig. 2. Pressure components (\(P_L, P_R, P_C\)) of the intraurethral pressure profile (\(P\)) corresponds to uroflow (\(Q\)).](image1)

![Fig. 3. Correlation between LC and \(Q_{\text{max}}/T\). \(Q_{\text{max}}/T = 1.09 \times \text{LC}^{-0.54}\), \(R^2 = 0.51\).](image2)

![Fig. 4. \(Q_{\text{max}}\)-V.V. relation with LC as a parameter.](image3)
When Qmax is used to compare urethral resistance, it is necessary to adjust VV to about the same levels. In the result, urethral LC can be calculated non-invasively from the uroflowmetrogram. It correlated with the horizontal to vertical ratio of the uroflowmetograms, Qmax/T, and the contribution rate was 51%. As Qmax reflected LC and VV to the same extent, Qmax/T better reflected LC compared to Qmax without being affected as much by VV.

Many factors affect Qmax and Qmax/T. However, it is clinically extremely useful to be able to evaluate the conditions of the urinary tract non-invasively with accuracy. Our results suggested that urethral LC can be evaluated by Qmax/T to some extent.

Table 1. Mean value of the groups

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
<th>Post TURP</th>
<th>Pre TURP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qmax/T</td>
<td>2.10±0.78</td>
<td>1.41±0.43</td>
<td>1.41±0.68</td>
<td>0.276±0.070</td>
</tr>
<tr>
<td>Qmax</td>
<td>25.2±9.1</td>
<td>18.7±4.0</td>
<td>18.8±6.0</td>
<td>9.19±2.50</td>
</tr>
<tr>
<td>LC</td>
<td>0.36±0.15</td>
<td>1.36±0.92</td>
<td>1.43±1.75</td>
<td>9.4±12.1</td>
</tr>
</tbody>
</table>

Mean±S.D.

Fig. 5. Significant difference among the groups in Qmax/T, Qmax and LC (p<0.05). Simplified characters show as follows. F: normal female group, M: normal male group, pre: preTURP group, post: postTURP group, NS: no significance.

REFERENCES


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和文抄録

尿流曲線の形と尿流曲線から計算された尿道の損失係数との関係についての考察

西本 憲一1，田代孝一郎1，吉田 直正1，張本 幸司1
西川慶一郎1，田中 智章2，仲谷 達也2，安田 耕作3

1生長会府中病院泌尿器科，2大阪市立大学大学院泌尿器病態学講座
3獨協医科大学越谷病院泌尿器科

尿流曲線の形は排尿状態を反映している。排尿のシミュレーションを使い尿流曲線の近似から計算された尿道の損失係数が尿流曲線の形を規定するパラメーターと相関するのか検討した。

合計161例の正常異常尿流曲線を使用した。さらに正常女性、経尿道的前立腺切除術前後の症例についても検討した。尿流曲線の形を表現するパラメーターの一つである最大尿流率（Qmax）と排尿時間（flow time, T）の比を計算した。一方、尿流曲線を排尿モデルで近似し、尿道の損失係数（LC）を計算した。

結果として、Qmaxとflow timeの比Qmax/TはLCと強い相関を認めた。

Qmax/Tは尿流曲線の横軸比であるが、排尿中の平均的な流量の加速の度合いを示している。一方尿道の損失係数LCは尿道の抵抗の一種と考えてよい。抵抗が大きい尿道では、尿流量の加速の程度が平均値とし

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