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

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

A total of 161 normal and abnormal uroflowmeterograms 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 uroflowmetergram, was calculated. The uroflowmetergrams 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 uroflowmetergram 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 uroflowmetergram, 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 uroflowmeterograms 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 uroflowmeterograms using three parameters regulating the shapes of uroflowmeterograms1,2 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 uroflowmeterograms using a voiding model3,4 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 uroflowmeterogram.

MATERIALS AND METHOD

A total of 161 normal and abnormal uroflowmeterograms 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).

Uroflowmeterograms were approximated using our...
Fig. 2. Pressure components (PL, PR, PC) of the intraurethral pressure profile (P) corresponds to uroflow (Q).

previously reported voiding model, and urethral LC and voided volume (VV) were calculated. 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, LC was calculated as follows. When the integral value of pressure loss during voiding time contributing to inertial, frictional and elastic resistance was PL, PR and PC, respectively (Fig. 2), and the total sum of energy used for elastic resistance during voiding was WL, LC = (PR + PC)/WL. VV was calculated by integrating the approximated flow rate. Age was not taken into consideration.

RESULTS

The relation of Qmax/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 Qmax and LC was similarly expressed by \( Q_{\text{max}} = 18.3 \times \text{LC}^{-0.56} \). When the contribution of VV on Qmax/T and Qmax was studied, the contribution rate of both LC and VV on Qmax/T calculated by multivariate analysis was\( R^2 = 0.55 \). The contribution rate of both LC and VV on Qmax 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 Qmax was 36% and the correlation coefficient was 0.6. The contribution rate of both LC and VV on Qmax was 67%. This indicated that the degree of contribution of LC alone was smaller on Qmax compared to Qmax/T, while the degree of contribution of both LC and VV was similar on Qmax. These results suggested that Qmax/T better reflected urethral LC compared to Qmax, and that the effects of VV were minimal on Qmax/T. Qmax/T is therefore more suitable compared to Qmax when examining patients with different VV.

Qmax 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 Qmax is about the same, Qmax is affected not by VV alone but also by LC to the same extent. When this relation is illustrated using a VV-Qmax nomogram, the relation of VV-Qmax is thought to change with urethral LC as a parameter (Fig. 4). That is, when VV is the same, Qmax increases as LC decreases and Qmax decreases as LC increases. This agrees with actual clinical phenomena.
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>$Q_{max}/T$</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>$Q_{max}$</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.

When $Q_{max}$ 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 uroflowmetrometers, $Q_{max}/T$, and the contribution rate was 51%. As $Q_{max}$ reflected LC and $VV$ to the same extent, $Q_{max}/T$ better reflected LC compared to $Q_{max}$ without being affected as much by $VV$.

Many factors affect $Q_{max}$ and $Q_{max}/T$. 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 $Q_{max}/T$ to some extent.

$Q_{max}/T$, $Q_{max}$ and LC were studied in 9 normal female subjects, 60 normal male subjects without urinary disturbance (included in the 161 cases studied) and 16 cases before and after TURP (8 patients) (Table 1). They were not studied according to $VV$. For example, there was no significant difference in $Q_{max}$ between male and female groups ($p=0.064$), but there was a significant difference in $Q_{max}/T$ between male and female groups ($p=0.032$) (Fig. 5). The ability of $Q_{max}/T$ to separate a difference among the groups is higher than that of $Q_{max}$. We previously reported that the normal value of $Q_{max}/T$ was 0.78 or more1), and LC equivalent to this value calculated from the regression line was 1.9 (Fig. 3). When the values of LC for both normal female and male subjects are considered, LC of 2 or less is normal, and from the LC value of 1.35±0.92 obtained from normal male subjects ($n=60$), LC of 4 or more can be regarded as abnormal. LC of 2 to 4 can be considered within the gray zone.

Urethral LC is smaller in normal female subjects compared to normal male subjects, reflecting the anatomical structure of the urinary tract. It is increased in BPH patients before TURP, but urethral resistance decreases and LC improves to about the same as those in normal male subjects after surgery. $Q_{max}/T$ also improves to normal levels after TURP. $Q_{max}$ is also higher in female normal subjects compared to normal male subjects and improves after TURP (Fig. 5).

Urethral LC can be calculated non-invasively from the uroflowmetry curve, and if it is used clinically, it can quantitatively express the conditions of the urinary tract. Moreover, our results indicated that as $Q_{max}/T$ reflects urethral LC, LC can be conveniently estimated from $Q_{max}/T$ to some extent.

REFERENCES

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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

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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の
1つである最大尿流量（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 は尿流曲線の縦横比であるが、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
て小さいと結論された。尿流曲線の形から尿道の損失
係数を推定できる。Qmax/T は Qmax に比較して排
尿量の影響が少なかった。Qmax/T は排尿量に依存
する程度が小さく排尿量の異なる症例を比較するのに
適当である。

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