Maximum and Average Urine Flow Rates in Normal Male and Female Populations—the Liverpool Nomograms

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Summary—The study of voiding in men and women has been handicapped by the lack of a normal reference range covering urinary flow rates over a wide range of voided volumes.

Normal volunteers (331 males and 249 females) were studied. Each voided once into a calibrated Dantec Urodyne 1000 micrograph. On a second occasion 282 men and 46 women voided. The maximum and average urine flow rates of the first voids in both sexes were compared with the respective voided volumes.

Nomogram charts, in centile form, for both the maximum and average urine flow rates were constructed using statistical transformations of the data. Males showed a significant decline in both urinary flow rates with age, although there was no statistically significant variation in either urine flow rate with respect to first versus repeated voiding. Females showed no statistically significant variation in either urine flow rate with respect to age, parity or first versus repeated voiding.

The maximum and average urine flow rates in both sexes showed an equally strong relationship to voided volume. No artificial restriction of voided volume, e.g. minimum 200 ml, appeared appropriate. These nomograms offer reference ranges for both maximum and average urinary flow rates in both sexes covering a wide range of voided volumes (15–600 ml).

The clinical usefulness of urinary flow rates has been attenuated by the lack of absolute values defining normal limits (Marshall et al., 1983). As urinary flow rates are dependent on voided volume (Drake, 1948; Drach et al., 1979a), these normal limits need to cover a wide range of voided volumes. Ideally, these should be in the form of nomograms.

The maximum and average urine flow rates are defined by the International Continence Society (Bates et al., 1977) and are those rates most useful clinically. The lower limits of normal are still unclear in both sexes. Recommended values for the lower limit of normal for the maximum urine flow rate in men range between 15 (Holm, 1962) and 20 ml/s (Kaufman, 1957); in women the values range between 12 (Massey and Abrams, 1988) and 20 ml/s (Fandl et al., 1982). A minimum rate of 15 ml/s is usually quoted if at least 200 ml have been voided (Farrar et al., 1976; Whitfield, 1985).

Torrens and Morrison (1987), in a review of uroflowmetry, criticised the nomograms of von Garrelts (1957) in men and Backman (1965) in women for their insufficient data and inadequate allowance for reduced scatter at the lower voided volumes. Siroky et al. (1979) constructed nomograms using data from a relatively small number of younger men. The nomograms of Jorgensen et al. (1985) and Kadow et al. (1985) were restricted to older men.

The aim of this study was to establish normal reference ranges in both sexes, for the maximum and average urine flow rates, over a wide range of voided volumes and in the form of nomogram charts.

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Patients and Methods
A series of 331 male volunteers (aged 16-64 years) and 249 female volunteers (aged 16-63) were deemed normal for the study. They denied previous bladder surgery (including cystoscopy) and any of the following symptoms of voiding difficulty: hesitancy, poor stream, need to strain to void, sense of incomplete emptying and the need to revoid immediately. The females also denied any urinary incontinence and the males denied the additional symptom of urgency and a history of more than 1 urinary tract infection.

All of the males were production workers in a large motor vehicle plant. Approximately 80% of the women were hospital staff and visitors; the remainder were women attending an outpatient infertility clinic. A further 85 male and 97 female volunteers with positive urinary symptomatology were excluded from further study.

All voiding studies were performed in a completely private uroflowmetry room/toilet, lockable from the inside and out with the hearing range of other staff and volunteers. A Urodyne 1000 microliterograph (Dantec, Denmark) was used. This machine uses the well evaluated (Rowan et al., 1977) spinning-disk principle. It is compact, quiet and non-disturbing in operation, with auto-start and stop facilities to remove any involvement of either staff or volunteers during the actual voiding studies.

Calibration was initially performed using the internal self-calibration programme on the apparatus and repeated at intervals to ensure consistency. Objective checking of the reading of voided volume, flow time and average flow rate was performed using known fluid volumes and time (stopwatch). Overall error of the average flow rate lay within the ±1 to 3% limit quoted by the manufacturer and well within the 5% limit acceptable to the International Continence Society (Rowan et al., 1987).

Volunteers were encouraged to attend with a full bladder. Each voided at least once; 282 men and 46 women voided on a second occasion. All studies were free flowmetry voids.

The maximum flow rate, average flow rate and voided volume were measured. If voiding was interrupted, the period(s) of interruption were excluded when calculating the flow time. All flow rates and times produced by the uroflowmeter’s computer were checked manually against the flow curve.

Maximum and average flow rates from the first voids of the 331 men and 249 women were compared with their respective voided volumes.

In order to establish nomograms of 1 variable allowing for a relationship with a second variable, it was necessary to estimate both the form for the relationship and the variability inherent in that relationship. This was most easily achieved by a statistical transformation of the data such that the 2 variables then showed a linear relationship and an approximately normal variance about that relationship.

Having assumed a form for the relationships between maximum and average urinary flow rates and the voided volume, we used standard multiple regression techniques to assess the possible effects of age in both sexes and parity in the women. Similarly, for the 282 men and 46 women who voided on a second occasion, it was possible to look for any systematic effect between voids.

For presentation, the nomograms have been expressed in centile form and transformed back to their original scales, giving a curvilinear appearance. The nomograms were produced using the SAS graphic package on an IBM 3083 computer (SAS, 1985).

Results
The median voided volumes in the first voids were 195 ml (men) and 171 ml (women).

The median age of the men was 49 years (range 16-64). The median age for the women was 32 years (range 16-63); 70% of the women were nulliparous, 10% and 14% had 1 and 2 children respectively, whilst 6% had more than 2 children.

The men showed a decline in both urinary flow rates with increasing age after allowing for voided volume. This decline was approximately 1.0 to 1.6 ml/s/10 years (maximum) and 0.6 to 1.0 ml/s/10 years (average). The women showed no dependence of either flow rate on either age or parity. Paired analysis showed no systematic difference in either sex between the first and second voids with regard to either flow rate.

In men, equations for the nomograms related flow rates with both voided volume and age. These became:

(a) \[ \sqrt{(\text{Maximum flow rate})} = 2.37 + 0.18 \times \sqrt{\text{(voided volume)}} - 0.014 \times \text{age} \]
   Root mean square error: 0.727

(b) \[ \sqrt{(\text{Average flow rate})} = 1.80 + 0.14 \times \sqrt{\text{(voided volume)}} - 0.011 \times \text{age} \]
   Root mean square error: 0.535

The ages of 35 and 60 were selected as represent-
relative median points for men under 50 years and men 50 years and over, respectively.

In women, it was unnecessary to subclassify the data on the basis of either age or parity. The final equations for the nomogram graphs were then:

(a) \( \ln(\text{maximum flow rate}) = 0.511 + 0.505 \times \ln(\text{voided volume}) \)

Root mean square error = 0.340

(b) \( \sqrt{\text{average flow rate}} = -0.921 + 0.869 \times \ln(\text{voided volume}) \)

Root mean square error = 0.640

Figures 1 and 2 show the Liverpool nomograms for the maximum and average urine flow rates respectively for men under 50 years. Figures 3 and 4 show the Liverpool nomograms for the maximum and average urine flow rates respectively for men 50 years and over. Figures 5 and 6 show the Liverpool nomograms for the maximum and average urine flow rates in women.

Both flow rates showed an equally strong relationship with voided volume in both sexes. The data sets for the studies in both sexes allowed estimation of centiles for both flow rates in the range 15 to 600 ml.

Figure 7 shows the data set for the maximum urine flow rate (men 50 years and over) superimposed on the respective nomogram. Figure 8 shows the data set for the average urine flow rate in women superimposed on the respective nomogram. These figures demonstrate the ability of the different nomograms to fit the data sets.

Figure 9 shows maximum urine flow rates from a large number of voids in one 35-year-old male volunteer, superimposed on the nomogram chart.

Discussion

These nomograms were constructed to provide normal reference ranges in both sexes for urinary flow rates, covering a wide range of voided volumes and in centile form. Nomograms in centile form have been found to be easily interpretable in some obstetric and paediatric situations (Chamberlain et al., 1975; Hensinger, 1976). The use of statistical transformations in their construction overcame the problems created by inaccuracy when untransformed standard deviations are used (Backman, 1965; Susset et al., 1973; Siroyk et al., 1979; Fantl et al., 1982). The data, especially for the maximum urine flow rate in women, have a greater scatter above the line of the mean. The use of untrans-
Fig. 2  Liverpool nomogram for average urine flow rate (men under 50 years: median 35).

Fig. 3  Liverpool nomogram for maximum urine flow rate (men 50 years and over: median 60).
Fig. 4  Liverpool nomogram for average urine flow rate (men 50 years and over: median 60).

Fig. 5  Liverpool nomogram for maximum urine flow rate in women.
Fig. 6  Liverpool nomogram for average urine flow rate in women.

Fig. 7  Maximum urine flow rate nomogram (men 50 years and over: median 60) with the data set used in its construction superimposed.
Fig. 8  Average urine flow rate nomogram in women with the data set used in its construction superimposed.

Fig. 9  Maximum urine flow rates from a large number of voids by 35-year-old male volunteer superimposed on the nomogram chart.
formed standard deviations could easily create excessively low limits for standard deviations below the mean.

The use of nomograms overcomes the dangers of referencing flow rates to any one voided volume. A maximum urine flow rate of 11 ml/s in men, or 15 ml/s in women, might fall just inside the fifth centile curve at 200 ml voided volume, although well outside the same curve at 400 ml. The normality of these flow rates may be then interpreted quite differently at these 2 voided volumes.

Artificial restriction of voided volumes within the nomogram in either sex, e.g. to above 150 or 200 ml, appeared inappropriate from our investigations. Attempts have been made to develop linear relationships in men between the various flow rates both above 150 ml (Drach et al., 1979b) and below 150 ml (Marshall et al., 1983). As the median voided volumes in our series were 195 ml (men) and 171 ml (women), approximately half of the voided volumes would not be explained by either method. There may be practical difficulties in waiting for male or female patients to collect bladder volumes over 200 ml. In some pathological conditions, patients may be unable to hold 200 ml (Ryan and Marshall, 1982; Abrams, 1983). The only restriction of voided volumes in our series is the limits of the data set (15–600 ml).

The equally strong relationship between maximum and average urine flow rates with voided volume in both sexes tends to suggest that the clinical use of either flow rate is equally valid. They are numerical representations of the same flow curve and tend to provide similar clinical information (Zinner, 1982). The centile rankings of the maximum and average urine flow rates are not, however, necessarily interchangeable in individual cases.

Both sexes showed a remarkable consistency in the centile rankings of the paired first and repeated voids. This was further witnessed in the multiple voids from the single 35-year-old male volunteer (Fig. 9) and the single 25-year-old female volunteer. There is, therefore, a need for data from a large number of normal volunteers in the construction of such nomograms, rather than multiple voids from a small number of patients (Susset et al., 1973; Fantl et al., 1982; Rollena et al., 1985). It can be concluded that in the majority of normal men and women, the centile rankings of successive voids will not differ widely. However further studies are necessary in order to justify the same conclusion in men and women with lower urinary tract dysfunction.

The previously suggested deterioration in male urinary flow rates with age (von Garrelts, 1957; Torrens, 1987) has been confirmed in this study. Ideally, 10-year age groupings would allow increased statistical accuracy within the nomogram charts. In clinical terms, a large number of nomograms might prove rather confusing.

Our results support the view of most authors that in women there is no significant dependence of urinary flow rates on age (Drach et al., 1979a; Fantl et al., 1982). The study of Torrens and Kavanagh (1987), supporting the opposite view, was not performed on asymptomatic women. Our finding of no significant effect of parity on flow rates in normal women supported the findings of Drach et al. (1979a) and Fantl (1982).

No systematic deterioration of flow rate in either sex was discernible at higher voided volumes, as previously observed in men (Drach et al., 1979a; Ryan and Marshall, 1982; Abrams et al., 1983).

These charts are offered as providing easily interpreted normal reference ranges in both sexes, for the 2 most commonly used urinary flow rates, over a wide range of voided volumes. Further studies are now under way to compare centile rankings of the flow rates of men and women at higher risk of voiding difficulties, and other lower urinary tract disorders, with the results of the normal men and women contained herein.

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References


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