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Variability of post-void residual urine volume in the elderly

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Abstract Residual urine volume, though clinically important as a diagnostic tool, is reported to be variable and unreliable. Variability was examined among 14 geriatric patients, mean age 77 years. Residual urine was measured by ultrasound at three different times of day on each of two visits separated by 2–4 weeks. Results were examined by analysis of variance. Mean residual urine was 154 ml. Between-patient variability was large [standard deviation (SD) 246 ml]. There was no significant difference between values in men and women, nor between visits. Within-patient variability was large because of a large systematic variation with time of day (SD 128 ml), with greatest volumes in the early morning. The inherent, random variability of the measurement was much smaller than this (SD 44 ml). If the physiological factors causing the temporal variation could be controlled, more reproducible measurements would be possible.

Key words Residual urine · Reproducibility · Diurnal variation · Geriatrics · Ultrasound

Introduction

In healthy adults the volume of residual urine in the bladder after voiding is only a few millilitres [7, 8]. Among male patients with benign prostatic hyperplasia, residual urine volume is frequently much larger than this. A volume greater than about 100 ml may be an indicator of poor voiding efficiency, possibly associated with bladder outlet obstruction [2]. Large volumes may be a precursor of acute urinary retention [4]. Among the geriatric population a large residual urine volume is common even in the absence of obstruction [6].

In spite of the generally recognized importance of the volume of residual urine, reports in the literature suggest that it is extremely variable and therefore not reliable as a diagnostic tool, for example in benign prostatic hyperplasia [3]. However, detailed examination of short-term and long-term variability, and of whether the variations are random or systematic, has not been reported.

As part of a larger study we have performed measurements of residual urine, using an ultrasound technique, in a group of elderly men and women who were referred to us for urinary incontinence. Residual urine was determined 3 times during a 24-h monitoring period (in the afternoon, evening and early morning) and these measurements were repeated 2–4 weeks later. The aims were to determine the random variability of residual urine volume measurement, in both the short and long term, and to determine any systematic variation that might contribute to the reported variability of the measurement.

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Materials and methods

Patients with symptoms of urinary incontinence were referred from a tertiary geriatric assessment and rehabilitation facility. Bedridden patients and those with an indwelling urethral catheter were excluded. Written informed consent was obtained from the patient and if necessary from a close relative. Drugs prescribed to influence bladder function were discontinued 1 week before the investigations. Other drugs judged necessary by the patient's physician were continued. Possible urinary infection was investigated and if present was treated before the study began.

Initial investigations included physical examination, history, assessment of activities of daily living (ADL) [9], cognitive testing with the Mini-mental State Examination (MMSE) [5] and 24-h monitoring of bladder function and residual urine on a specialized unit [6]. On the basis of these investigations an intervention was recommended. Two to 4 weeks later the 24-h monitoring was repeated. For this study, only patients who had a conservative intervention (e.g. fluid intake adjustment or regular toiletting) were included. None had surgical or medical intervention. Patients in whom any of the six residual urine measurements required by the protocol were missed were excluded.

During each visit for 24-h monitoring, residual urine was measured 3 times, in the afternoon (1200–1600 hours), in the evening (1900–2300 hours) and in the early morning (0500–0800 hours), using an ultrasound scanner (Pie Medical 1100). The bladder volume was calculated by combining the dimensions of a transverse and a sagittal scan [11]. We have previously validated this method [6]. Residual urine volumes were measured within 15 min of the preceding void.

The measurements of residual urine – six determinations on each patient, made at three different times of day and on two different visits – were examined statistically using the program SPSS/PC+. Statistical distributions, random variability and possible systematic differences were first investigated by descriptive graphical methods and non-parametric tests. Repeated-measures analysis of variance was then used to find possible systematic variation with the time of day at which the measurement was made or with the visit number (1 or 2); the remainder of the variability was split up into a part reflecting real differences between patients and parts reflecting the inherent random variability – technical and/or physiological – of the measurement in a single patient.

Results

Fourteen patients, seven women and seven men, qualified for the study. Their average age was 77 years, range 65–90 years. Their mean score on the MMSE was 22/30, range 15–29/30, and the median ADL score was C, range A–G. In addition to being incontinent, three patients had an underlying clinical diagnosis of parkinsonism, two of Alzheimer disease, one of cerebrovascular disease and one of multi-infarct dementia. Only 2 of the 14 patients were receiving diuretic medication. Thus distortion of results by artificially increased diuresis between voiding and residual volume determination was unlikely.

Figure 1 shows the 6 residual volume measurements in all 14 patients. This illustration, which is similar to one published for benign prostatic hyperplasia patients [3], emphasizes the variability of the measurements in any individual patient. The variability tended to increase with increasing residual volume. The overall average value of residual urine volume was 154 ml.

Figure 2 shows the distribution of values of the evening residual volume on the first visit. Measurements made at other times of day and/or on the second visit had similar distributions. Because the distributions are clearly non-normal, non-parametric statistical methods are preferable. For analysis of variance, non-parametric methods are not available; this problem is considered below.

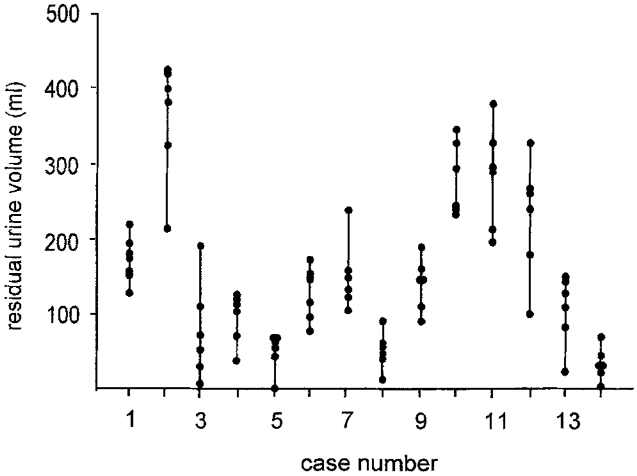

Fig. 1 Post-void residual urine volumes in 14 elderly patients. *Each circle* represents one measurement

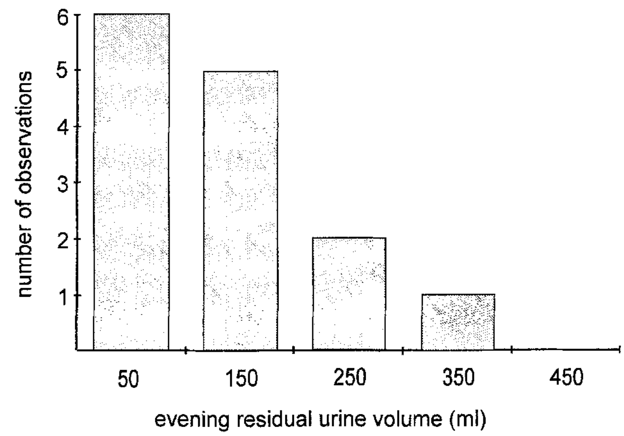

Fig. 2 Histogram showing the distribution of evening residual urine volumes on the first visit

Figure 3 shows the mean residual urine volumes in the afternoon, evening and early morning, averaged over the 14 patients and the 2 visits. The early morning mean residual urine is significantly larger than the evening and afternoon values ($P = 0.0110$ and $P = 0.0010$ by Wilcoxon's test). There is no significant difference between the afternoon and evening values.

The average residual urine was 149 ml on visit 1 and 159 ml on visit 2. There is no significant difference between these two values ($P = 0.59$ by Wilcoxon's test). There was no significant difference between the average residual volumes in men and women ($P = 0.85$ by the Mann-Whitney test).

Analysis of variance was then applied to the residual urine data. In principle, data used for analysis of variance should have a normal distribution and the variability (variance) should not depend on the actual value. For residual urine volumes neither assumption is accurate (see Figs. 1, 2). The assumptions are not critical, but a logarithmic transformation is often applied to

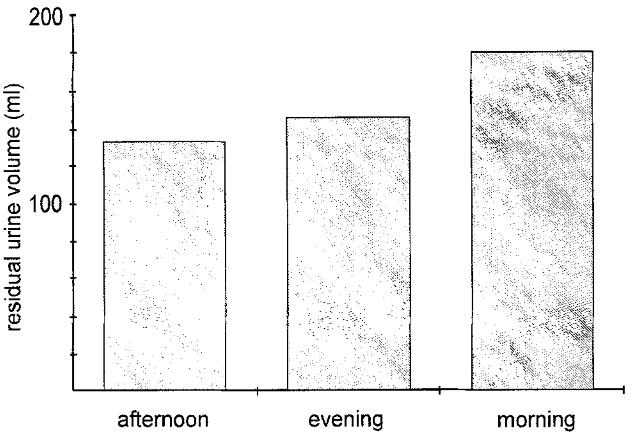

Fig. 3 Mean residual urine volumes in the afternoon, evening and early morning, averaged over all 14 patients and the 2 visits. Early morning residual urine is significantly larger than either of the other two

such data to make the distribution more nearly normal and to stabilize the variance [1]. A transformation of this type was in fact used, but because it makes the analysis more difficult to follow, only the results of analysis of the raw, untransformed data are shown in Table 1. The sums of squares of differences from the mean are partitioned among the various sources of variability discussed in "Materials and methods". The square root of each of the mean sums of squares can be regarded as a standard deviation describing the size (in millilitres) of that source of variability (see Table 1).

These results were confirmed by analysis of variance of the logarithmically transformed variable:

$Z = \log(\text{residual volume} + 100\ \text{ml})$

The value 100 ml was chosen to make the distribution of Z approximately normal, as judged graphically from normal probability plots [10]. A standard deviation for Z corresponds to a percentage change in the variable (residual volume + 100 ml) and thus to a standard deviation of residual volume (in millilitres) that depends on the actual volume of residual urine.

Table 1 shows that the overall differences from patient to patient are large compared with the mean (mean value = 154 ml; between-subject standard deviation = 246 ml, see line 2). There is a highly significant variation with time of day (standard deviation = 128 ml, see line 5). The variability from visit to visit is much smaller (standard deviation = 44 ml, line 3) and is no larger than the inherent variability of the measurement (see estimates of this standard deviation on lines 4, 6 and 8). The average sum of squares for these three lines, obtained by dividing the combined sums of squares by the combined degrees of freedom, corresponds to a standard deviation of 44 ml, describing the inherent random variability of a single measurement. The interaction between time of day and visit attained borderline significance (line 7), implying that the variation of residual urine with time of day was not identical on the first and second visits, and confirming the importance of time of day.

The standard deviations derived from analysis of the raw data and shown in Table 1 are global estimates, applicable to average values of residual urine. Analysis based on the transformed variable Z confirmed the relative orders of magnitude of the mean squares, standard deviations and significance levels in Table 1, but yielded standard deviations that increased with increasing residual urine volume, as suggested by Fig. 1. For example, the standard deviation describing the inherent random variability of a single measurement increased from 20 ml for very small residual volumes to 80 ml for residual volumes of 300 ml. The standard deviation describing the variation with time of day was about 3 times larger, increasing from 67 ml for very small residual volumes to 267 ml for volumes of 300 ml.

Conclusions

In this elderly population the inherent random variability of residual urine determination by ultrasound

Table 1 Results of analysis of variance of residual urine data

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares (variance)	Standard deviation (ml)	F test and significance
Between subjects					
1. Constant	1 997 692	1	1 997 692		$F = 33.0$
2. Within cells	785 830	13	60 448	246	$P < 0.001$
Within subjects					
3. Visit	1905	1	1905	44	$F = 0.63$
4. Within cells	39 177	13	3014	55	$P = 0.44$
5. Time of day	32 915	2	16 457	128	$F = 11.3$
6. Within cells	37 849	26	1456	38	$P < 0.001$
7. Interaction: visit by time of day	16 517	2	8259	91	$F = 4.2$
8. Within cells	50 986	26	1961	44	$P < 0.05$

was relatively small. The extra variability over a period of 2–4 weeks was no greater than this inherent random variability.

The variation actually observed in an individual patient was much larger, consistent with results reported for men with benign prostatic hyperplasia [3]. The larger variation was systematically related to the time of day at which the determination was made. The residual urine volume was significantly larger in the early morning than at other times. Thus the volume of residual urine was strongly influenced by factors that changed over relatively short periods (24 h). These factors are presumably physiological, and may be related to hormonal status, to physical activity or to the volume in the bladder prior to voiding. If they could be identified and controlled, measurement of residual urine volume could be made more reproducible and more useful for diagnostic purposes. In principle it should be possible to reduce the variability by a factor of about 3. Identification of the factors causing changes in residual urine volume might also help to understand and ultimately prevent episodes of acute urinary retention.

From a clinical point of view it may be important to identify patients who have residual volumes that are consistently greater than a certain cut-off value, e.g. 100 ml. Six of the 14 patients in this study had residual urine volumes greater than 100 ml, while only 3 had residual volumes consistently under this value. For 5 of the 14 patients (36%) the residual volume was sometimes greater and sometimes less than 100 ml, so that in these cases a single measurement of residual urine volume might have given a clinically misleading result.

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