Original Study

Circadian Variation in Post Void Residual in Nursing Home Residents With Moderate Impairment in Activities of Daily Living

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postvoid residual
residual fraction

Abstract

Background: Despite the conflicting evidence about postvoid residual (PVR) and its variation in time and corresponding voided volume (VV), studies with urinary diaries and systematic measurements of PVR after each void have never been conducted in nursing home (NH) residents.

Objective: To describe the circadian rhythm of PVR and residual fraction (RF, the net quantity of PVR) and to identify the time window with the highest PVR and RF.

Design, setting, and participants: A multicentre prospective study conducted between 2014 and 2015 in 5 Belgian NHs. A convenience sample of cognitively intact residents completed a 24-hour frequency volume chart with PVR.

Results: Participants (n = 73) had a median age of 84 years (interquartile range 82-89) and moderate impairment of activities of daily living; 69% were women.

In residents with nocturia, mean PVR was higher during the night [45 mL (26 e 80)] than during the day [36 mL (18 e 61)]. In residents without nocturia no difference was detected.

In spite of the variation between diurnal and nocturnal VV and PVR in residents with nocturia, all residents emptied their bladder as effectively during daytime as during nighttime [mean RF = 20% (12 e 32)].

Maximum PVR and RF in residents with nocturia (n = 57) showed a circadian variation. The highest PVR and RF were found during the day. The PVR and RF of the first morning void were an indicator of the maximum nocturnal PVR and RF.

Conclusions: PVR and VV should be measured in NH residents during the waking hours (first morning void excepted) to detect the clinically relevant maximum PVR and RF.

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measured after a normal toilet visit instead of after a uroflowmetry but warns that there is no evidence regarding the reliability of the PVR. Although it is advisable to ask if the voiding was similar to a typical micturition in a patient's daily life, unrepresentative results may be obtained when voiding occurs in unfamiliar surroundings. Furthermore, no recommendations exist about the time of the day at which the measurement must be performed. Measurement of PVR in NH residents seems most reliable after an unforced void and in their familiar environment. PVR can be quantified in a noninvasive manner by making use of portable ultrasound devices that can be used by trained nurses.

Despite the conflicting evidence about PVR and its variation in time, no studies with urinary diaries and PVR measurement after each void in frail older people have been published. Studying PVR in frail older people without acute illness is more practically feasible in NHs than in the community.

Knowing the circadian variation of PVR in NH residents allows to determine a time window in which the measurement of PVR, and by extension RF, produces the highest (and thus most diagnostically relevant) values.

Consequently, this study in a population of cognitively intact NH residents was performed (1) to describe the circadian rhythm of PVR and RF and (2) to identify the part of the day with the highest PVR and RF.

Methods

This multicentre prospective observational study was conducted between April 2014 and February 2015. The study population consisted of a convenience sample of 157 Belgian NHs with 775 residents in total. All NHs have single rooms with private facilities.

Nurses of the NHs screened all 775 residents for inclusion in the study. Inclusion criteria were as follows: cognitively intact (no indication of dementia on the Belgian modified Katz Index), >65 years without indwelling urinary catheter, urostomy, fecal incontinence, hemodialysis, preterminal or terminal state of life. Exclusion criteria were as follows: a positive screen on the Mini-Cog (additional screening for dementia in all participating residents), continuous leakage, and global polyuria (24-hour urine production >2.8 L).

For study purposes, the scores on the 6 items of activities of daily living (ADL) (ie, bathing, dressing, transfer, going to the toilet, continence, and eating) on the Belgian modified Katz Index were reduced into the scores yes/no for independence in each of the 6 functions. A score of 6 indicates fully preserved function, a score of 4 indicates moderate impairment, and a score of 2 or less indicates severe functional impairment.

In the frequency-volume urine chart with PVRs (FVCPVR), the following parameters were registered for 24 hours: voided volume (VV) (mL), urine (g), PVR (mL), time of going to bed, and time of getting up. In each toilet, a bidet was placed to allow the resident to void in a sitting position. After every void, the resident called the study nurse, who measured VV, leakage, and PVR using a portable ultrasound device (BladderScan BVI 9400, Verathon, Inc) within 30 minutes after voiding. A previous study showed that Bladderscan BVI is an accurate alternative to bladder catheterization for noninvasive estimation of PVR.

In this real-life study, voiding habits were not interfered by toileting routines, and all residents were allowed free fluid and solids intake. Participants got a nondisruptive nighttime care approach. Data collection was performed by nursing students and the investigators. The nursing students were trained in data collection and the use of the portable ultrasound device.

Measurements derived from the FVC_PVR were defined in accordance with the report from the standardization subcommittee of the ICS. Urine production was interpreted as the sum of all voided and incontinence volumes. Bladder capacity (BC) was calculated as the sum of VV and PVR. Low BC was defined as <300 mL and nocturnal polyuria (NP) as a nocturnal urine volume of >33% of 24-hour urine volume. RF is the net quantity of PVR. The following formula was used with PVR and accompanying void:

\[
RF = \frac{PVR}{PVR + VV} \times 100\%
\]

SPSS Statistics v.23.0 (IBM Corp, Armonk, NY) was used for data analysis. Missing values in questionnaires or FVCPVR were not estimated or replaced, except in case of one missing value in the FVCPVR during daytime. Those missing values were replaced with the mean of the corresponding diurnal values (n = 14). Results are reported in terms of median and interquartile range. Nonparametric tests were used to compare unpaired (Mann-Whitney U test) and paired continuous variables (Wilcoxon test). Statistical significance was defined as a p value <.05.

We obtained the local ethics committee approval (2014/0293), and all participating residents gave their written informed consent.

Results

Breakdown of Participants

From the 157 informed residents, a written informed consent was obtained from 115 residents, and 94 of them completed the study successfully. The reasons for not ending or being excluded from the study are presented in Figure 1.

Resident Characteristics

The median age of the 73 studied residents was 84 years (range, 82–89), and 70% (n = 51) were women. The median total score on the Katz Index was 3 (range, 1–4), indicating a moderate impairment in ADL. From the 73 participating residents, 556 voids were recorded.

Comparison of Diurnal and Nocturnal FVC_PVR Characteristics

Nocturia was a prevalent symptom (>1 void/night: 78% [n = 57], ≥2 voids/night: 41% [n = 30]), which could be explained by the presence of NP (n = 42), a low BC (n = 6), or a combination of both (n = 9). A comparison between nocturnal and diurnal FVC_PVR characteristics in residents with and without nocturia is presented in Table 1.

All residents had a higher mean nocturnal VV and BC compared with daytime values.

![Fig. 1. A flow chart of the study’s progress, detailing participant numbers during inclusion, data collection, and data cleaning.](image)
Residents without nocturia showed no difference between mean diurnal and nocturnal PVR, whereas residents with nocturia had higher mean nocturnal PVR compared with their diurnal PVR. Between both groups, no difference was found in mean PVR.

The mean RF showed that despite the higher mean nocturnal PVR in residents with nocturia, on average the residents emptied their bladder as effectively at night as during the day.

**Maximum PVR and RF**

Maximum diurnal and nocturnal PVR and RF were significantly higher than mean PVR and RF ($P < .001$), respectively. The maximum PVR in 24 hours was 106 mL (range, 56–161), and no difference was detected between maximum diurnal and nocturnal PVR (including first morning void) in all residents. Maximum PVR was <100 mL in 47% (n = 34) of residents, between 100 and 200 mL in 38% (n = 28), and >200 mL in 15% (n = 11).

For further analysis of the maximum PVR and RF, the first morning void was studied independently of the nocturnal void(s) in residents with nocturia ($\geq 1$ void/night) (Figure 2).

No difference was found between maximum diurnal PVR and PVR of the first morning void in residents without nocturia. In residents with nocturia, the highest PVR was the maximum diurnal PVR. The maximum RF was calculated with the corresponding VV of the maximum diurnal and nocturnal PVR. In all residents, the maximum diurnal RF [43% (range, 20–59)] was significantly higher ($P < .001$) than the RF of the first morning void [17% (range, 9–37)].

In 57 residents with nocturia ($\geq 1$ void/night), the PVR and RF of the first morning void and maximum nocturnal void were not different, which suggests that PVR and RF of the first morning void are indicators of the maximum PVR and RF of nocturnal voids in residents with nocturia (Figure 2B and D). The highest PVR and RF were found during daytime, with exclusion of the first morning void.

**Discussion**

This is the first study in which PVR was systematically measured after each void during 24 consecutive hours in NH residents with moderate ADL impairment. The circadian rhythms of PVR and RF were described and the part of the day with the highest PVR and RF was determined. The mean diurnal and nocturnal PVR were not different between residents with and without nocturia, although residents with nocturia had higher nocturnal PVR as compared to diurnal PVR.

Previous studies have reported PVR in community-dwelling and hospitalized older people.\(^6\)\(^7\)\(^8\)\(^9\) The range of the measured PVR in the current study population was different from those in other studies, probably because of the used method (24-hour registration vs 1 to maximum 3 times/d) and the population characteristics. PVR has a known variability depending on the time at which it was measured as well as on differences in the voided volume, which was confirmed in this study.\(^6\)\(^7\)\(^8\)\(^9\) Intrahindividual variability was previously described with the highest PVR in the early morning (5–8 AM).\(^6\) In this study, PVR of the first morning void was significantly lower than the maximum diurnal PVR.

Our results provide a new insight into PVR in institutionalized older people because nocturnal PVR were recorded and the influence of voided volume was eliminated by using RF. Mean diurnal and nocturnal RF between residents with and without nocturia was not different, suggesting RF is more constant than PVR for the evaluation of bladder emptying effectiveness.

**Clinical Significance**

The clinical implication of this finding is that the measurement of PVR should be performed during the waking hours (with exclusion of the first morning void).

Although different recommendations for the assessment of LUTS exist, none of them is specific for NH residents. The 5th ICI recommends active case finding, followed by assessment of potentially treatable conditions, quality of life, desire and goals for therapy, patient and caregiver preferences, targeted physical examination, urine analysis, bladder diary or wet checks, and PVR in specific patients. Selected frail older people who need PVR testing are people with diabetes mellitus, prior urinary retention or high PVR, recurrent UTI, medications with effect on bladder emptying, severe constipation, persistent UI despite treatment, or abnormal urodynamics.\(^7\)

**Future Research**

The additional value of this study is the description of the circadian variation of PVR and RF in NH residents. Nevertheless, prospective studies in other populations (community-dwelling older people and NH residents with severe ADL impairment) and in (older) patients with LUTS are needed to confirm whether the findings of this study can be generalized. Although we found a statistically significant difference between mean diurnal and nocturnal PVR, the clinical impact of this small difference is not clear and perhaps not relevant.

**Table 1**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Residents Without Nocturia, n = 16 Median (IQR)</th>
<th>P Value vs Without Nocturia</th>
<th>Residents With Nocturia, n = 57 Median (IQR)</th>
<th>P Value vs Without Nocturia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (h:min)</td>
<td>15:00 (14:32–15:56)</td>
<td>.001</td>
<td>14:15 (13:30–15:35)</td>
<td>.001</td>
</tr>
<tr>
<td>Total urine volume (mL)</td>
<td>583 (411–899)</td>
<td>.088</td>
<td>750 (606–1078)</td>
<td>.096</td>
</tr>
<tr>
<td>Urine output (mL/h)</td>
<td>38 (33–65)</td>
<td>.756</td>
<td>54 (40–74)</td>
<td>.069</td>
</tr>
<tr>
<td>No. of voids</td>
<td>5 (4–6)</td>
<td>.001</td>
<td>6 (5–7)</td>
<td>.017</td>
</tr>
<tr>
<td>Mean VV (mL)</td>
<td>130 (72–179)</td>
<td>.001</td>
<td>152 (106–198)</td>
<td>.001</td>
</tr>
<tr>
<td>Total UI (g)</td>
<td>14 (0–56)</td>
<td>.169</td>
<td>0 (0–5)</td>
<td>.100</td>
</tr>
<tr>
<td>Mean PVR (mL)</td>
<td>27 (17–49)</td>
<td>.002</td>
<td>36 (18–61)</td>
<td>.009</td>
</tr>
<tr>
<td>Mean BC (mL)</td>
<td>169 (119–198)</td>
<td>.002</td>
<td>196 (138–263)</td>
<td>.001</td>
</tr>
<tr>
<td>Mean RF (%)</td>
<td>22 (8–39)</td>
<td>.587</td>
<td>19 (11–32)</td>
<td>.660</td>
</tr>
</tbody>
</table>

IQR, interquartile range.

\(\circ\) = diurnal; \(\bigcirc\) = nocturnal; BC = VV \div VPR; RF = PVR/(PVR \times VV) \times 100%.

*P values < .05.
The etiology of circadian variation of PVR and RF could be explained by the hypothesis that inadequate bladder filling volume leads to less effective detrusor contraction during daytime. The cause of the inadequate bladder filling volume before voiding could be insufficient fluid intake and/or voiding before the urge to void (resulting from voiding habits or voiding programs). This presumed causal link must be investigated in a study with an accurate registration of fluid intake and bladder sensation in an FVCPVR in residents with and without bothersome LUTS supplemented with urodynamics. In the light of these findings the use of an FVCPVR seems valuable for investigating the influence of PVR, BC, and RF in residents with and without LUTS. In contrast to urodynamics, an FVCPVR approximates real-life parameters more closely. The value of FVCPVR in the diagnostic process for LUTD in older people still has to be demonstrated.

The most optimal duration of a bladder diary to achieve reliability for the diary parameters is 3 days. A 24-hour FVCPVR was used in this study, during which full support was provided by the researchers and nursing students. This support has supposedly led to a sufficiently accurate registration of the parameters. A 24-hour registration seems acceptable in this population because most of the days they have a standard daily schedule with regard to fluid intake, activity, and sleep pattern. However, this finding still needs to be confirmed in a study with at least a 72-hour FVC.

An unexpected finding of this study is that VV, PVR, and BC were not different between residents with and without nocturia. The nocturnal urine output was higher in residents with nocturia, which indicates that NP may be the primary cause of nocturnal voids. Residents without nocturia had more UI compared to residents with nocturia. This distribution could be hypothesized to result from a diminished bladder sensation leading rather to nocturnal UI than to nocturia.

Strengths

The strength of this study is the systematically measured PVR during 24 consecutive hours, which was made possible by the 24-hour presence of the researchers and nursing students, who captured every single void and PVR.

The design of the study in the real world without any intervention in fluid intake or voiding habits increases the external validity to NH residents with moderate ADL impairment.

Study Limitations

Data regarding neurologic impairment and other comorbidities, medication, and drinking volumes were not collected, although the presence of diabetes mellitus, neurologic disorders, sleep disorders, excessive evening fluid intake, nighttime drinking, diuretic drugs, etc may affect the voiding characteristics. The increased likelihood of comorbidities and polypharmacy made it difficult to study their...
impact on LUTS, especially because of the limited number of participants in the study.

Conclusions

This was the first study measuring PVR systematically after every void over 24 hours in a population of NH residents with moderate ADL impairment. Diurnal and nocturnal PVR did not differ in residents without nocturia, but residents with nocturia showed significantly higher nocturnal PVR compared with daytime. However, this difference may not be clinically relevant.

Important for clinical practice is that on average residents empty their bladder equally effectively over 24 hours, because their VV follows the same day-night pattern as the PVR.

Considering RF is the net quantity of PVR, it could be a valuable parameter in the evaluation of bladder dysfunction in NH residents because the circadian variation of this parameter is very limited.

The measurement of the PVR and VV in NH residents during the waking hours (the first morning void excluded) provides the possibility to determine the highest PVR and RF over 24 hours.

References


