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# In vitro test of different urine-meters in an experimental bladder-drainage model: prevention of ascending contamination depends on construction of the urine-meter

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## Abstract

**M**odern urine-meters are provided with the urine collection bag directly attached to the measuring device, thus providing a closed collection system. The systems vary, however, in respect to how the measuring devices are emptied into the urine collection bag. Using an *in vitro* ascending contamination model we compared three systems: the Unometer (Unomedical), the Bard Urinometer and the Curity Urinometer (Kendall), which all differ in the methods of emptying. The urine collection bags were inoculated with *Pseudomonas aeruginosa*, and subsequently sampled daily at six different sites for up to seven days in order to determine the degree and timing of ascending contamination of the systems. Unometer was significantly less contaminated at the urine-meter level at day seven than both Bard (0/8 vs. 4/4,  $P=0.002$ ) and Curity (0/8 vs. 8/8,  $P=0.0002$ ), respectively, as well as significantly less contaminated in the infusion-catheter above the urine-meter at day seven than Bard (0/8 vs. 4/4,  $P=0.002$ ), but not so as compared to Curity (0/8 vs. 1/8,  $P=1.0$ ). The Bard and Curity systems empty the devices by tilting thereby probably contaminating the devices, while the Unometer is emptied via a non-return valve in the bottom of the device.

## Introduction

Urinary tract infections (UTIs) are among the most frequent nosocomial infections. In a recent study measuring the prevalences of nosocomially-acquired UTIs (NAUTI) in 141 European hospitals, an overall incidence of 3.55 episodes/1,000 patient-days or a prevalence of 10.65/1,000 was reported (Bouza et al, 2001).

Risk factors for NAUTI are well known with introduction and handling of urinary- or bladder catheters as one of the major factors (Maki et al, 2001).

A closed drainage system is the best prevention against UTI during catheterisation (Maki et al, 2001). 'Closed' also means as few

breaks in the system as possible (Maki et al, 2001).

The major part of bladder catheter infections arise as extraluminal infections, i.e. ascending on the exterior side of the catheter, while around one-third of the infections are intraluminal due to contamination of the system (Tambyah et al, 1999).

Several factors can reduce the occurrence of UTI during catheterisation such as antibiotic therapy at introduction, meatal care, disinfective devices in the catheter systems such as electric current, povidone-iodine pellets, silverdiazine-coated catheters and others (Khoury et al, 1989; Mulhall et al, 1993; Wong et al, 1995; Stickler et al, 1996; Reiche et al, 2000; Maki et al, 2001; Ekmekcioglu et al, 2002).

The presence of a urine output device or urine-meter was, in a retrospective study by Platt et al (1982), found to reduce the risk of UTI, which was shown also in a prospective clinical study (Blenkham, 1985).

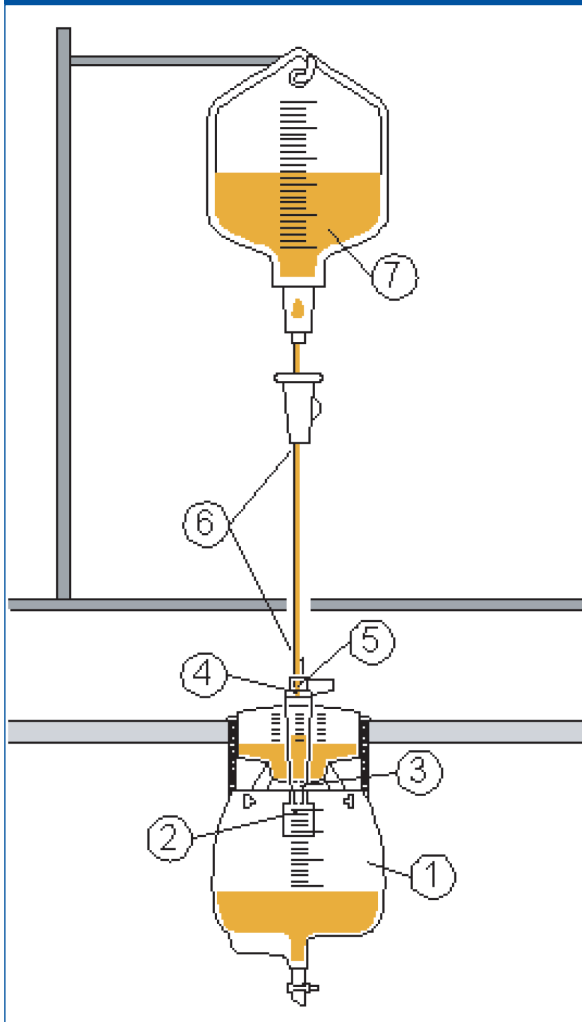
The authors have previously shown in an experimental *in vitro* bladder-drainage model that the presence of a urine-meter postpones the ascending contamination with *Pseudomonas aeruginosa* probably due to the construction of the urine-meter, i.e. long distance from catheter inlet to drainage outlet (Rasmussen et al, 1996).

New types of urine-meters have since then appeared which apparently have focused more upon the ease of use of the device than prevention of ascending contamination. Several of the new systems have attached the urine drainage bag behind or at the side of the urine-meter thereby reducing the overall size of the device and thus enabling the urine-meter drainage bag system to hang on the side of the bed without the bag touching the floor, which can be the problem with urine-meter systems having the urine drainage bag attached at the bottom of the urine measuring device.

The authors have not been able to find any published studies comparing these different urine-meter types for their ability to prevent ascending infection. The purpose of the present study was to use the ascending bladder-drainage model to compare various types of newly-developed urine-meters.

**Figure 1. In vitro bladder drainage model. The digits refer to:**

- (1) Urine-collecting bag with fluid
- (2) Non-return valve with filter in the bottom of the urine-meter (3)
- (4) and (5) Lower and upper part of the catheter inlet to the urine-meter
- (6) Infusion-line catheter (with infusion-rate regulator) connecting the urine-meter to the bag (7) filled with artificial urine and alluding the bladder/kidneys. Samples were procured at different days from the parts numbered (1) to (5)



### Materials and method

#### *In vitro bladder drainage model*

Figure 1 shows the in vitro model. The urine-meter was connected via an infusion-line to a bag, representing the bladder.

At day one the bag was filled with 10l of fluid simulating urine, i.e. Mueller-Hinton broth diluted 1:9 with sterile 0.9 per cent saline, which flowed continuously at 1.4l/day through the system. The urine-meter was connected to a urine collecting bag, which for all the systems studied followed with the device.

To detect retrograde contamination, the urine bag was filled with 100ml of the same Mueller-Hinton broth: saline solution containing  $10^8$  colony forming units (cfu) of *Ps. aeruginosa* (a clinical strain resistant towards gentamicin). This bacterium was chosen because it is known to produce biofilm and because such bacteria are commonly found in the urine when bladder catheters are introduced (Maki et al, 2001).

During the experiment, the urine-meter was emptied twice a day according to the manufacturer's instruction for each system. After emptying the urine-meters into the bags, these were emptied via

the bottom outlets twice a day as well.

The system was operated for a maximum of seven days and samples taken days two, four and seven after inoculation from the different parts of the system as represented by numbers one to seven in Figure 1.

Since sampling from sites inside the urine-meter, i.e. numbers (3) to (5) to five in Figure 1, could only be performed by dismantling the urine-meters, the experiments were conducted in such a way so that two to four systems were tested for the intended number of days and then removed from the experiment.

Three to four urine-meters were always tested in parallel, nine to ten systems at a time, in order to secure the same conditions for the systems compared.

### Microbiology

Samples of 0.25ml to 0.5ml were removed and cultured for +/- growth on brome-thymole-lactose agar (Statens Serum Institut, Denmark), which allows growth of Gram-negative enteric bacteria including *Pseudomonas* spp. only.

The bacteria cultured were routinely checked for species diagnosis according to laboratory routine, as well as susceptibility towards gentamicin by tablet diffusion (Rosco, Denmark) on Danish Blood Agar (Statens Serum Institut, Denmark). No contamination with other bacterial species occurred at any time during the study.

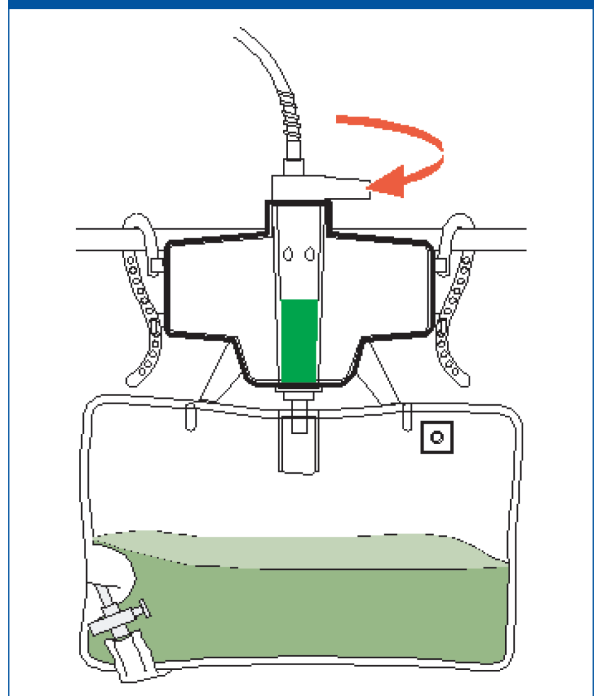
### Urine-meters

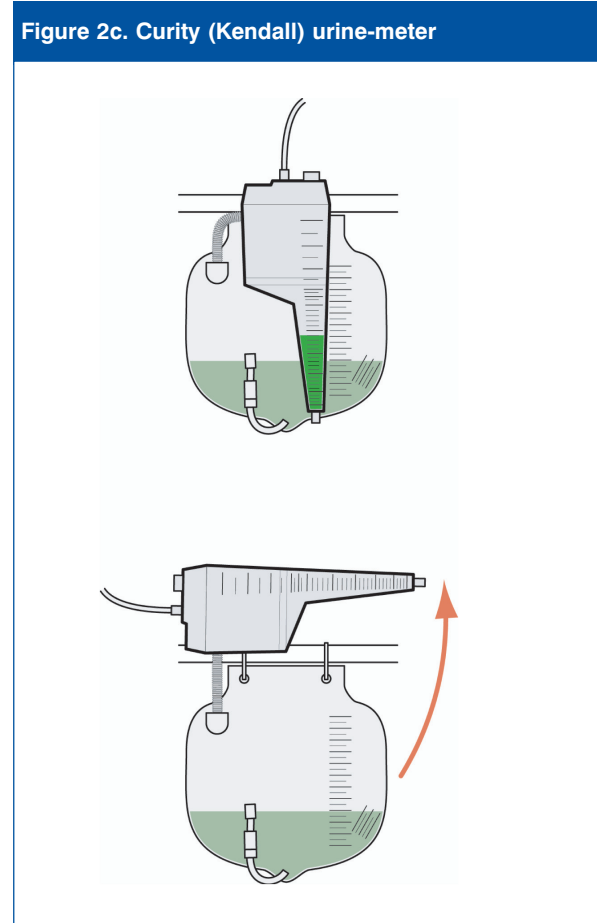
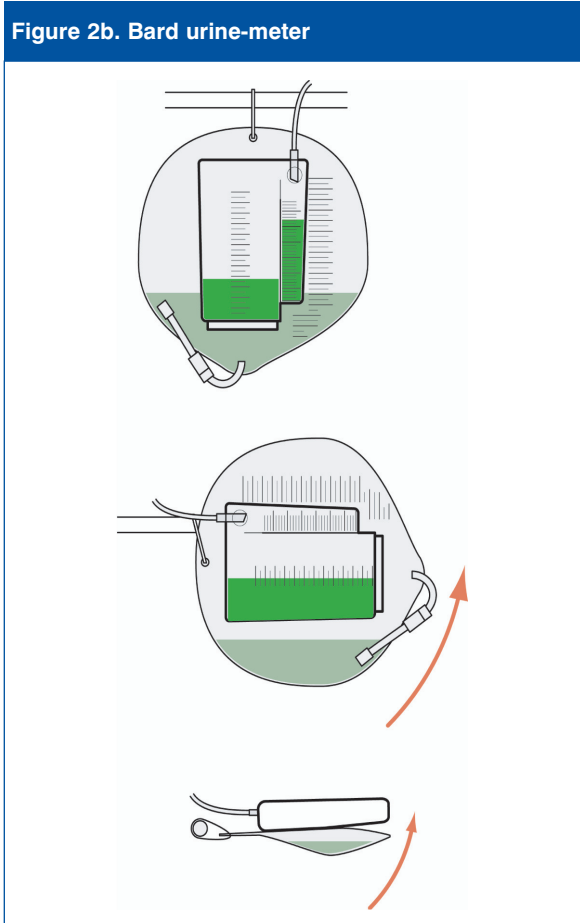
Figure 2a to c shows the different types of urine-meters tested. Figure 2a shows the type represented by Unometer (Unomedical). This system has the emptying devices in the bottom of the urine-meter, where the urine collecting bag is connected, while the emptying device is opened by a tap placed above the urine-meter (see Figure 2a).

The connection between the urine-meter and the urine collecting bag is constructed with a non-return valve and a 5µl filter.

Figure 2b shows the Bard urine-meter, where the urine collection bag is connected via an opening on the back side of the urine-meter. The urine-meter is emptied by tilting the device backwards as indicated in Figure 2b.

**Figures 2a-c. The urine-meters tested. The arrows illustrate how the urine-meters are emptied**  
Figure 2a. Unometer urine-meter





**Table 1. Results of infection of the urine-collecting bag with *Ps. aeruginosa* in the in vitro bladder-drainage model shown as the number of positive cultures/total number of systems tested at the respective site of sampling (urine bag, urine-meter or infusion line (catheter) above the urine-meter at days two, four or seven after inoculation. Shaded: any positive cultures**

Product (total no. tested)	Urine-collecting bag			Urine-meter			Infusion line above urine-meter		
	2	4	7	2	4	7	2	4	7
<b>Bard (12)</b>	4/4	4/4	4/4	2/4	4/4	4/4	0/4	0/4	4/4
<b>Curity (16)</b>	4/4	4/4	8/8	0/4	1/4	8/8	0/4	0/4	1/8
<b>Unometer (16)</b>	4/4	4/4	8/8	0/4	0/4	0/8	0/4	0/4	0/8

Figure 2c illustrates the Curity urine-meter (Kendall). This urine-meter has the urine collecting bag connected at the side of the device, which is emptied by tilting the meter sideways.

The advantage of Bard and Curity systems should be, that by placing the urine collecting bag either behind or sideways to the urine-meters, the whole device takes up less space when hung on the side of the hospital bed, in contrast to the former urine-meters, where the bag hangs below the meter and therefore takes up more space.

**Statistics**

For comparison of the frequency of culture-positive urine-meters, the Fishers exact test was used with a double-sided P-value < 0.05 considered significant.

**Results**

The authors tested for ascension of the bacteria above the urine-meter, which if positive would allow free access of the bacteria to the rest of the system, i.e. reach the bladder in a few days.

In 4/4 of the Bard- and 1/8 Curity urine-meters ascending contamination had passed from the urine-meter to the infusion-line above the non-return valve in seven days.

Two of four Bard urine-meters were contaminated already at day two, and all systems at day four. Curity was only slightly better with one of four urine-meters infected at day four, but all, i.e. 8/8, contaminated at day seven (see Table I for the results of the experiment).

In contrast, no Unomedical urine-meters (total of 0/8) were contaminated at day seven, and in no cases (0/8) had the contamination ascended above the level of the urine-meter at day seven. Unomedical was significantly less contaminated at the urine-meter level than Bard at day four (0/4 vs. 4/4,  $P = 0.03$ ) but not significantly so as compared to Curity (0/4 vs. 1/4,  $P = 1.0$ ).

Unometer was significantly less contaminated at the urine-meter level at day seven than both Bard (0/8 versus 4/4,  $P = 0.002$ ) and Curity (0/8 vs. 8/8,  $P = 0.0002$ ), respectively. Unometer was significantly less contaminated in the infusion-catheter above the urine-meter at day seven than Bard (0/8 vs. 4/4,  $P = 0.002$ ), but not so as compared to Curity (0/8 vs. 1/8,  $P = 1.0$ ).

### Discussion

First of all it should be stressed that the in vitro model used in the present study is only a surrogate for the situation where a urine-meter device is used in vivo in a patient.

The artificial, heavy contamination with *Ps. aeruginosa* may not reflect the real situation, where only the outer portion of the outlet is contaminated with few bacteria and takes much longer time to contaminate the interior of the urine bag. But this type of study may generate ideas of how clinical studies should be performed. However, while in vivo validation of the in vitro model is highly recommended, this may be very difficult, not the least for ethical reasons. In only one prospective clinical study was the frequency of UTIs measured and found to be reduced when an urine-meter device was used as compared with the closed bladder system without a urine-meter (Blenkham, 1985).

Already in the first study the authors had found that the introduction of an urine-meter into a closed catheter-drainage system delayed an ascending contamination in the device (Rasmussen et al, 1996).

A urine-meter with emptying device in the bottom of it was also found to be more effective in preventing ascending contamination than systems, which had to be tilted in order to empty the urine from the urine-meter to the collecting bag (Rasmussen et al, 1996).

The reasons for this were the probable contact of contaminated 'urine' with the catheter inlet when tilting the urine-meter. These findings were repeated in the present study.

The authors compared two types of systems: 1) Bard and Curity (see Figure 2b and 2c) with urine-collecting bags connected directly to the urine-meters in such a way that tilting the urine-meters either backwards or to the side emptied the urine directly into the bags via openings without non-return valves; and 2) Unometer (Figure 2a) with urine-collecting bag connected below the urine-meter where the urine-meter does not need to be tilted. In this system, there is a relatively long distance from the catheter-inlet portion and the outlet. This probably reduces the risk of contamination of the catheter-inlet with infected urine.

The latter system was significantly better than the urine-meters with collecting bags attached to the side or behind the meter to postpone deliberate ascending contamination, i.e. in none of the devices emptied via the bottom of the urine-meter did bacteria ascend above the catheter inlet after a seven-day period (see Table I).

Since ascending infections originating in the urine collection bag in closed catheter systems represent about 30% to 40% of all catheter infections (Tambyah et al, 1999), it is recommended to consider the type of urine-meter used for the purpose of reducing the number of NAUTI related to the use of bladder catheters. This would appear to be pertinent especially in intensive care units, where this type of devices are most frequently used.

The results of this and the author's former study (Rasmussen et al, 1996) indicate that it should be considered whether this type of testing should become mandatory before introducing such systems in the clinic. However, these results can only be validated by comparison of the different types of urine-meters in clinical studies.

### Acknowledgements

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