Safely Reducing Manual Urine Microscopy Analyses by Combining Urine Flow Cytometer and Strip Results

Sylvie Roggeman, MD, and Zahur Zaman, MD, PhD

Key Words: Flow cytometer; UF-100; Urine microscopy; Urine strips

Abstract

We aimed to reduce the number of manual urine microscopy examinations safely by cross-interpretation of the Sysmex UF-100 (TOA Medical Electronics, Kobe, Japan) and urine strip results such that microscopy would be performed if there was discordance between the UF-100 and urine strip results. We also evaluated the usefulness of the optional UF-100 expert software. We performed 2 studies: study 1 to establish review rules for eventual microscopic examination; study 2, a validation study. Our review rates were 40% and 48% and those of UF-100 software were 16% and 32% for the 2 studies. Our false-positive and false-negative results, among the samples not flagged for microscopic review, were acceptably low. We did not find a good correlation between the microscopic classification of RBC morphologic features and the classification given by the UF-100. Since incorporation of the automated urine strip reader and the UF-100 in routine use, our manual microscopy has been reduced to less than 40%.

Microscopic examination and chemical analysis of urine remain essential for diagnosis, prognosis, and follow-up of patients with renal and urinary tract diseases. However, urine sediment microscopy, being time consuming and labor intensive, adds considerably to the cost of providing laboratory services. Attempts have been made to reduce the number of urine microscopic analyses by screening the urine samples with urine strips and performing microscopy on the samples that give positive results. Such simplification has been reported to produce significant losses in diagnostic yields.[1-3] Another approach to increase productivity has been to automate urine microscopy on an image analysis system[4] and, more recently, on a Sysmex UF-100 flow cytometer (TOA Medical Electronics, Kobe, Japan). The latter counts the formed elements in urine on the basis of their light scattering, fluorescence, and impedance properties. The principles of analysis[5] and evaluation[6-9] have been published. The analyzer counts RBCs, WBCs, squamous epithelial cells, bacteria, and casts but reports the presence of pathologic casts, tubular and transitional epithelial cells (small round cells), yeast-like cells, crystals, and spermatozoa semiquantitatively as positive. Now, an optional expert system has been added to the software. This expert system interprets the urine strip and UF-100 results and then generates suggestive interpretative messages (flags), which may be used as review rules for manual microscopy. The results of the unflagged specimens would not require verification by manual microscopy and could be validated and released, should one so choose.

We performed a study to examine the possibility of safely reducing the number of manual microscopy analyses

by cross-interpretation of the results of the UF-100 flow cytometer and of an automated urine strip reader. We evaluated the diagnostic accuracy of the UF-100 and its optional expert software by comparing all UF-100 and the strip reader results with those of the reference method, manual microscopy. This enabled us to generate our own review rules, determine what would be the diagnostic loss if manual microscopy were not performed on the specimens not flagged for microscopic review, and establish whether any UF-100 results would be released that were inconclusive or apparently uninterpretable because UF-100 results were positive and the urine strip reader results were negative or vice versa and, thus, mutually discordant for certain parameters.

Materials and Methods

Patients and Samples

Study 1

During a 4-week period, 1,029 freshly collected urine samples of hospital inpatients submitted for urine microscopy were randomly selected for study 1. The patients consisted of 470 females (mean age, 50 years; range, 1 month to 96 years) and 559 males (mean age, 47 years; range, 1 month to 87 years). The specimens originated from nephrology (n = 321; of these, 132 were renal transplant recipients); pediatrics (n = 161); surgery (n = 36); intensive and emergency departments (n = 105); oncology (n = 24); internal medicine, including consultation (n = 278); geriatrics (n = 43); and other clinical departments (n = 61).

Study 2

The review and release rules generated in study 1 were validated in study 2 using 554 other urine samples. The patients consisted of 284 females (mean age 52 years; range, 1 month to 95 years) and 270 males (mean age, 56 years; range, 1 week to 93 years). The source distribution was similar to that of study 1.

Urine Collection and Analysis

Random urine, voided in a plastic beaker, was aspirated (10 mL) into Uridraw evacuated conical plastic tubes (Terumo Europe, Leuven, Belgium) and sent to the laboratory by means of a pneumatic tube system (Aerocom GmbH & Co, Kernen, Germany). For very young infants, urine was first collected in a plastic bag attached to the external genital area.

After mixing, an aliquot of the urine sample was applied to a disposable plastic Uriglass counting chamber (A. Menarini Diagnostics, Florence, Italy) for microscopic counting and examination of the formed elements. This was followed by strip analysis on an automated urine strip analyzer, Super Aution, using Uriflet S 9UB strips (A. Menarini Diagnostics). This strip enables semiquantitative analyses of glucose, protein, bilirubin, urobilinogen, pH, heme (hemoglobin/myoglobin), nitrite, and leukocyte esterase. Super Aution measures specific gravity by the refractive index method, color by reflectance measurement at 4 wavelengths, and turbidity by a transparency index method. It uses the Sysmex racks as sample holders. After Super Aution the sample racks were transferred to the Sysmex UF-100 urine flow cytometer for quantitative analysis of RBCs, WBCs, squamous epithelial cells, bacteria, and casts and semiquantitation of pathologic casts, tubular and transitional epithelial cells (small round cells), yeast-like cells, crystals, and spermatozoa.

Urine Microscopy

Manual microscopy was used as the "gold standard." Microscopic identification and counting were performed by phase-contrast microscopy (×400) on uncentrifuged urine samples using disposable Uriglass counting chambers. Each 1-μL chamber is divided into 10 large squares. Each square has a volume of 0.1 μL and is subdivided into 16 small squares. RBCs, WBCs, cylinders, and tubular cells were counted in 5 × 16 squares. The results for RBCs and WBCs were expressed as the number of cells per microliter of urine (our reference values for RBCs, 6/μL or less; for WBCs, <10/μL) and those for casts and tubular cells as trace, 1+, or 2+. Other cells, crystals, and bacteria were counted in 2 × 16 squares, and the results also were expressed as trace, 1+, and 2+. For each type of formed element, the semiquantitative scale corresponds to a certain number per microliter.

Sysmex UF-100

We determined the microscopic review rate by using the review messages (flags) generated by the UF-100 expert software. The flags are as follows: (1) "high total count" when the total number of particles is 250,000/μL or more; (2) conductivity of the sample is too high or too low; (3) problem with morphologic discrimination of RBCs; (4) "myoglobin?/lysed RBC?" when hemoglobin/myoglobin detected by the strip is disproportionately more than the RBCs found by the UF-100; (5) "hematuria?" when the number of RBCs per microliter is disproportionately much greater than the hemoglobin value; (6) "pathologic cylinders?" when pathologic cylinders are more than 1/μL; (7) "casts?" if hyaline cylinders are more than 3/μL; (8) "old sample?" if bacteria per microliter are proportionately much more than WBCs per microliter; (9) "sterile pyuria?" when the WBCs per microliter are proportionately much

Table 1
Our Rules for Generating Flags That Led to Microscopy of the Flagged Specimen*

Formed Element	UF-100 Result	Strip Result
RBCs	>30/μL and	Hemoglobin, <0.06 μg/dL
	<20/μL and	Hemoglobin, ≥0.06 μg/dL
	≥20/μL and ≤30/μL and	Hemoglobin, <0.03 μg/dL or >0.1 μg/dL
WBCs	>30/μL and	<25/μL
	<20/μL and	≥25/μL
	≥20/μL and ≤30/μL and	<25/μL or >75/μL
Hyaline cylinders	>3/μL and	Protein, <100 mg/dL
Pathologic cylinders	≥1/μL	—
Small round cells	>2/μL	—
Squamous epithelial cells	>50/μL	—
Yeast-like cells	>30/μL	—
High total count	>250,000/μL	—
Conductivity	≤5 millisiemens/cm or ≥38 millisiemens/cm	—

* Reference limits in the UF-100 software (Sysmex, TOA Medical Electronics, Kobe, Japan) were as follows: RBC, <25/μL; WBC, <25/μL; hyaline cylinders, <3/μL; pathologic cylinders, <1/μL; yeast, <10/μL; small round cells, <1/μL; and epithelial cells, <30/μL.

more than bacteria per microliter; and (10) "proteinuria?" when protein detected by the strip is more than 120 mg/dL. It was assumed that in routine use of the UF-100 expert software, the results of the unflagged specimens (whether positive or negative) would be deemed not to require microscopic review and thus would be validated and released. The reference limits in the UF-100 software were as follows: RBCs, fewer than 25/μL; WBCs, fewer than 25/μL; hyaline cylinders, fewer than 3/μL; pathologic cylinders, fewer than 1/μL; yeast cells, fewer than 10/μL; small round cells, fewer than 1/μL; and squamous epithelial cells, fewer than 30/μL.

We also generated our own review rules **Table 1**, based on the analysis of manual microscopy, UF-100, and urine strip reader data. If there was concordance between the strip and UF-100 results, microscopy was deemed unnecessary, and the results were validated and released. When there was a discordance between the UF-100 and strip results, the sample underwent microscopy. We defined *discordance* as complete disagreement between the 2 results, ie, one is positive and the other is negative. In addition, when the numbers of pathologic casts (casts with inclusions) and yeast-like cells were greater than our cutoffs of 1/μL or more and 50/μL or more, respectively, the sample also was examined under a microscope. One sample could be flagged for more than 1 parameter.

Statistical Analysis

Diagnostic sensitivities and specificities, receiver operating characteristic (ROC) curves, correlations, and regression calculations were performed with the aid of the Analyse-It computer package (Analyse-It Software, Leeds, England). In all calculations, manual microscopy was used as the reference method.

Results

Comparing UF-100 Expert Software and Our Own Review Rules

With the review rules of Sysmex UF-100 expert software and with our own rules generated in study 1, 16.1% (166/1,029) and 39.7% (408/1,029) of all samples, respectively, would have required manual microscopy. In the validation study (study 2), the review rate with our review rules was 48% and for Sysmex UF-100 expert software it was 32%.

Red Blood Cells

An ROC curve was constructed for the UF-100 data on RBC counts using manual microscopy as the reference method. The area under the curve was 0.83 (95% confidence interval, 0.81-0.86). On this curve, an RBC cutoff of 20/μL on the UF-100 corresponded to a sensitivity of 58% and a specificity of 89%.

Manual microscopy was positive for RBCs (ie, > 6/μL) in 443 of 1,029 cases. For the same 1,029 samples, the Sysmex expert software generated 83 (8.1%) "hematuria?" review flags. If microscopy were not done on the unflagged samples, as would be the case in routine use, 186 (18.1%) would be reported as false-negative results **Table 2**. In 135 cases (13.1%), inconclusive results would be released since in these cases there was mutual discordance between the UF-100 and the strip results (ie, one was positive and the other was negative).

With our own review rules, 35% of 1,029 samples were flagged for manual microscopy. Of the 621 unflagged samples (60.3%), 565 were concordant by all 3 methods, with 102 being positive and 463 negative **Table 3**. There

Table 2
Diagnostic Accuracy, Relative to Manual Microscopy, of Results for Samples Not Flagged by UF-100 Expert Software*

	Study 1				Study 2			
Parameter	**TP (%)**	**TN (%)**	**FN (%)**	**FP (%)**	**TP (%)**	**TN (%)**	**FN (%)**	**FP (%)**
RBCs	116 (11.3)	515 (50.0)	186 (18.1)	16 (1.6)	87 (15.7)	207 (37.4)	61 (11.0)	23 (4.2)
WBCs	157 (15.3)	564 (54.8)	56 (5.4)	56 (5.4)	93 (16.8)	236 (42.6)	22 (4.0)	27 (4.9)
Hyaline cylinders	1 (0.1)	778 (75.6)	46 (4.5)	8 (0.8)	1 (0.2)	333 (60.1)	42 (7.6)	2 (0.4)
Pathologic cylinders	0 (0)	823 (80.0)	7 (0.7)	3 (0.3)	0 (0)	369 (66.6)	9 (1.6)	0 (0)
Yeast	0 (0)	821 (79.8)	11 (1.1)	1 (0.1)	0 (0)	375 (67.7)	3 (0.5)	0 (0)
Small round cells	37 (3.6)	328 (31.9)	10 (1.0)	458 (44.5)	22 (4.0)	130 (23.5)	3 (0.5)	223 (40.3)
Squamous epithelial cells	18 (1.7)	749 (72.8)	15 (1.5)	51 (5.0)	7 (1.3)	334 (60.3)	2 (0.4)	35 (6.3)

FN, false negative; FP, false positive; TN, true negative; TP , true positive.
* For study 1, n = 833 specimens not flagged of 1,029 total specimens; for study 2, n = 378 specimens not flagged of 554 total specimens. Percentages are based on the total numbers of specimens. In routine use, these results would be released without microscopic review. For proprietary information, see the footnote for Table 1.

Table 3
Diagnostic Accuracy, Relative to Manual Microscopy, of Results for Samples Not Flagged by Our Review Rules*

	UF-100 Results							
	Study 1				Study 2			
Parameter	**TP (%)**	**TN (%)**	**FN (%)**	**FP (%)**	**TP (%)**	**TN (%)**	**FN (%)**	**FP (%)**
RBCs	102 (9.9)	463 (45.0)	53 (5.2)	3 (0.3)	85 (15.3)	174 (31.4)	20 (3.6)	5 (0.9)
WBCs	138 (13.4)	462 (44.9)	12 (1.2)	9 (0.9)	86 (15.5)	185 (33.4)	6 (1.1)	7 (1.3)
Hyaline cylinders	0 (0)	617 (60.0)	4 (0.4)	0 (0)	0 (0)	283 (51.1)	1 (0.2)	0 (0)
Pathologic cylinders	0 (0)	620 (60.3)	1 (0.1)	0 (0)	1 (0.2)	283 (51.1)	0 (0)	0 (0)
Yeast	1 (0.1)	619 (60.2)	1 (0.1)	0 (0)	0 (0)	281 (50.7)	3 (0.5)	0 (0)
Small round cells	11 (1.1)	553 (53.7)	3 (0.3)	54† (5.2)	13 (2.3)	229 (41.3)	1 (0.2)	41† (7.4)
Squamous epithelial cells	9 (0.9)	597 (58.0)	8 (0.8)	7 (0.7)	1 (0.2)	272 (49.1)	2 (0.4)	9 (1.6)

FN, false negative; FP, false positive; TN, true negative; TP , true positive.
* For study 1, n = 621 specimens not flagged of 1,029 total specimens; for study 2, n = 284 specimens not flagged of 554 total specimens. Percentages are based on the total numbers of specimens. In routine use, these results would be released without microscopic review. For proprietary information, see the footnote for Table 1.
† When the UF-100 reference value for small round cells is raised to 2/µL, 54 is reduced to 26 and 41 to 22.

were 3 false-positive results (0.3% of the total) and 53 false-negative results (5.2% of the total). Of the latter, 3 were clinically significant. But no inconclusive results were reported. In the validation study (study 2), among the 284 unflagged samples, there were 5 false-positive results (0.9% of the total) and 20 false-negative results (3.6% of the total) for RBCs (Table 3); only 2 (0.4% of total) of the latter were clinically significant.

White Blood Cells

The ROC curve for the UF-100 data for WBCs, with manual microscopy as the reference method, yielded an area under the curve of 0.88 (95% confidence interval, 0.86-0.91). From this curve, a WBC cutoff of 20/µL on the UF-100 gave diagnostic sensitivity and specificity of 82% and 83%, respectively.

By manual microscopy, 321 (31.2%) of 1,029 study 1 samples were positive for WBCs. The Sysmex UF-100 expert system does not have review rules, other than the reference limit of fewer than 25/µL, for WBCs. Using our own review rules, 217 samples (21.1%) required manual microscopy for WBCs. Of the 621 (60.3% of the total) not requiring manual microscopy for any parameter, 603 were concordant with microscopy results; 138 were positive and 462 negative (Table 3). There were 12 false-negative results, and of these, 4 were clinically significant. In study 2, 213 (38.7%) of 554 samples were positive for WBCs. Among the unflagged samples, there were 7 false-positive and 6 false-negative results (Table 3); only 2 of the latter were clinically significant.

Casts

In study 1, manual microscopy was positive for hyaline cylinders in 56 (5.4%) of 1,029 cases. The UF-100 expert software flagged 72 samples (7.0% of the total) for microscopy; 48 flags were for "casts?" and 24 for "protein?"

Of the 833 samples (81% of the total) not flagged by the UF-100 expert software for any of the parameters, 539 gave concordant results by microscopy, UF-100, and protein; all were negative. Eight were false-positive results, 46 were

false-negative results (Table 2), and in 270 cases (26.2% of the total), inconclusive results would have been reported because the UF-100 and the strip results were discordant.

With our review rules, among the unflagged samples, there were 4 false-negative results for hyaline cylinders, no false-positive results, and no inconclusive results (Table 3). For the pathologic cylinders, 18 (1.8% of the total) were positive by manual microscopy. Among the unflagged samples, our review rules yielded 1 false-negative result and no false-positive results in study 1 (Table 3). By comparison, the UF-100 software produced 7 false-negative and 3 false-positive results (Table 2).

In study 2, manual microscopy yielded only 6 positive cases for pathologic cylinders. Among the unflagged samples, with our rules, there were no false-negative or false-positive results (Table 3), but with the UF-100 software rules, there were 9 false-negative and no false-positive results (Table 2).

Epithelial Cells

By microscopic examination, 63 (6.1%) of 1,029 samples were positive for tubular/bladder epithelial cells (small round cells) in study 1, as were 48 (8.7%) of 554 in study 2. With a cutoff of 1 small round cell on the UF-100, the 2 studies yielded 458 and 223 false-positive results, respectively, among the unflagged samples (Table 2). These could be safely reduced to 54 or 26 for study 1 and 41 or 21 for study 2 by raising the cutoff to 2 small round cells per microliter, respectively (Table 3).

For squamous epithelial cells, 44 (4.3%) of 1,029 samples were positive by microscopy in study 1, as were 13 (2.3%) of 554 in study 2. With a cutoff of 30 squamous epithelial cells per microliter, among the unflagged samples, there were 51 false-positive results in study 1 and 35 in study 2 (Table 2). These false-positive results were reduced to 7 and 9, respectively, for studies 1 and 2 when the cutoff was raised to 50/μL (Table 3).

Yeast

By manual microscopy, 39 (3.8%) of 1,029 samples were positive in study 1, as were 25 (4.5%) of 554 in study 2. Among the samples not flagged for review by the UF-100 software, there were 11 false-negative results in study 1 and 3 false-negative results in study 2 (Table 2). Our review rules for yeasts gave 1 false-negative result and no false-positive results among the nonreview samples (Table 3). In study 2, 3 false-negative results were found among the unflagged samples.

RBC Morphologic Features

The UF-100 detects morphologic features by the size of the RBC as defined by forward scatter and distribution width values. In 214 samples, with 25 RBCs per microliter or more by the UF-100, the percentages of isomorphic and dysmorphic RBCs were determined under the microscope, and the results were compared with those of the UF-100 **Figure 1**. There was no acceptable relation between the microscopically determined percentage of dysmorphic RBCs and their UF-100 classification.

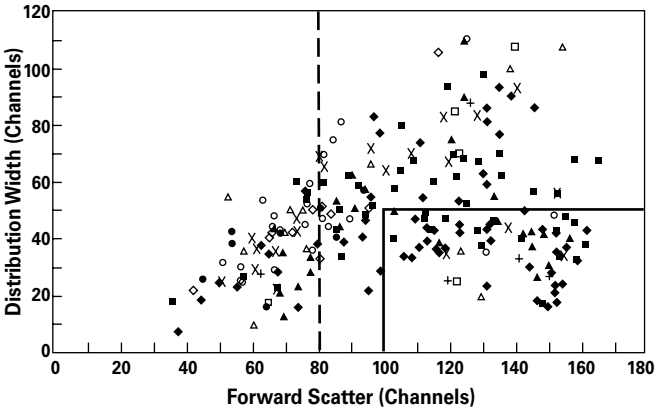

Figure 1 Scattergram of RBC morphologic features as determined by the UF-100 (for proprietary information, see the footnote for Table 1) and microscopic examination. UF-100 defines forward scatter (Fsc) >100 and distribution width (DW) <50 as "isomorphic" (area enclosed by thick lines); Fsc <80 as "dysmorphic" (area to the left of the broken thick line), and the rest as "mixed." Microscopically determined morphologic features (dysmorphic RBCs) are represented as follows: closed diamond, 0%-9%; closed square, 10%-19%; closed triangle, 20%-29%; x, 30%-39%; open square, 40%-49%; closed circle, 50%-59%; +, 60%-69%; open triangle, 70%-79%; open circle, 80%-89%; and open diamond, 90%-100%.

Discussion

We evaluated the feasibility of safely reducing the number of manual microscopic analyses by cross-checking the urine strip and UF-100 results such that concordant results would be released but samples showing discordance between the strip and UF-100 results or being flagged for infringement of a review rule would be reviewed manually under a microscope. In this way, only conclusive results would be released. To make the process acceptable to local clinicians, our review rules were deliberately made quite stringent. With our rules, the review rate in study 1 was 40% (of all the microscopy requests) and in study 2 was 48%. With the review rules of the UF-100 software, the review rates for the respective studies were 16% and 32%. Our review rates also were higher than those of Lun et al.[10] The

explanation for our high review rate lies in the extensiveness of our review rules and limited scope of the UF-100 software and of the review rules of Lun et al.[10] The Sysmex UF-100 software does not flag all discrepancies between the strips and the UF-100, and, other than the reference limit, it contains no review rules for WBC counts. This means that not only is the review rate lower, but also many discrepant and therefore inconclusive results are released. For their review criteria Lun et al[10] looked only at the discrepancies in RBC and WBC counts between the UF-100 and the urine strips.

The review rates for the Sysmex and by our own rules in study 2 were much greater than those in study 1. One possible explanation for this may be that in study 2, there were more samples from kidney and pancreas transplant recipients and patients undergoing chemotherapy. Zaman et al[11] observed, for example, that, because of the presence of pancreatic esterases, urine samples from kidney and pancreas transplant recipients give discordant results for leukocyte esterase and WBC counts.

With microscopy as the gold standard, our false-negative rates in both studies were acceptably low for all the parameters except perhaps for RBCs (Table 2). Closer examination of the cases revealed that, except for 3 cases in study 1 and 2 cases in study 2, we would not have missed anything clinically significant. The high false-positive rates for the small round cells (epithelial cells) and the squamous epithelial cells (Table 2) were due to low UF-100 reference limits for these parameters (1/μL for small round cells and 30/μL for squamous epithelial cells). These values can safely be raised to 2 or 3/μL for small round cells and to 50/μL for squamous epithelial cells. When this is done, the false-positive rates for these parameters drop, respectively, to 26 and 7 for study 1 and 22 and 9 for study 2 (Table 3).

The UF-100 also provides morphologic differentiation of the RBC as isomorphic, dysmorphic, or mixed population. This feature is intended as an aid to diagnosing glomerular hematuria[12] and is based on the commonly held belief that dysmorphic RBCs are glomerular in origin.[13,14] This idea is no longer wholly sustainable since dysmorphic cells occur in urine samples of patients without glomerulonephritis[15,16] and even in people with normal renal function.[17] The acanthocytes or G1 cells described as markers of glomerular hematuria[18-20] have good diagnostic specificity but poor sensitivity.[15,21] In the present study, unlike the findings of Lun et al,[10] we found no clearly discernible relation between the UF-100 classification and the microscopically determined percentages of isomorphic and dysmorphic RBCs (Figure 1). At this stage, we do not make use of the algorithm for RBC morphologic features of the UF-100. Instead, we perform morphologic analysis under a microscope.

Since incorporation of the automated urine strip reader and the UF-100 in our urine workstation, manual microscopy has been reduced to less than 40%. A substantial number of these are requests for analysis of RBC morphologic features. This reduction in manual workload has enabled us to reduce daily occupancy of the urine workstation by 2 full-time equivalent technologist positions.

From the Department of Laboratory Medicine, University Hospital Leuven, Leuven, Belgium.

Address reprint requests to Dr Zaman: Dept of Laboratory Medicine, University Hospital Leuven, Herestraat 49, B-3000 Leuven, Belgium.

Acknowledgments: We thank Merck Eurolab (Leuven, Belgium) and A. Menarini Diagnostics (Zaventem, Belgium) for providing the apparatus and the reagents.

References

1. Valenstein PN, Koepke JA. Unnecessary microscopy in routine urinalysis. *Am J Clin Pathol*. 1984;82:444-448.
2. Shaw ST Jr, Poon SY, Wong ET. "Routine urinalysis": is the dipstick enough? *JAMA*. 1985;253:1596-1600.
3. Resnick M. Comment on simplifying urinalysis. *Clin Chem*. 1985;31:450-451.
4. Roe CE, Carlson DA, Daignault RW, et al. Evaluation of the yellow IRIS: an automated method for urinalysis. *Am J Clin Pathol*. 1986;86:661-665.
5. Nakomoto H. Automated urinalysis. *Sysmex J Int*. 1996;6:168-172.
6. Fenili D, Pirovano B. The automation of sediment urinalysis using a new urine flow cytometer (UF-100). *Clin Chem Lab Med*. 1998;36:909-917.
7. Ben-Ezra J, Bork L, McPherson RA. Evaluation of the Sysmex UF-100 automated urinalysis analyzer. *Clin Chem*. 1998;44:92-95.
8. Langlois MR, Delange JR, Steyaert SR, et al. Automated flow cytometer compared with automated dipstick reader for urinalysis. *Clin Chem*. 1999;45:118-122.
9. Kouri TT, Kahkonen U, Malmaniemi K, et al. Evaluation of Sysmex UF-100 urine flow cytometer vs chamber counting of supravitally stained specimens and conventional bacterial cultures. *Am J Clin Pathol*. 1999;112:25-35.
10. Lun A, Ziebig R, Priem F, et al. Routine workflow for use of urine strips and urine flow cytometer in the hospital laboratory. *Clin Chem*. 1999;45:1305-1307.
11. Zaman Z, Roggeman S, Cappelletti P, et al. Evaluation of Aution Max AX-4280 automated urine test-strip analyser. *Clin Chem Lab Med*. 2001;39:649-657.
12. Hyodo T, Kumano K, Haga M, et al. Detection of glomerular and non-glomerular red blood cells by automated urinary sediment analyzer. *Jpn J Nephrol*. 1995;37:35-43.
13. Birch DF, Fairley KF. Haematuria: glomerular or non-glomerular [letter]? *Lancet*. 1979;2:845-846.
14. Fairley KF, Birch DF. Hematuria: a simple method for identifying glomerular bleeding. *Kidney Int*. 1982;21:105-108.

15. Zaman Z, Proesmans W. Dysmorphic erythrocytes and G1 cells as markers of glomerular hematuria. *Pediatr Nephrol*. 2000;14:980-984.
16. Pollock C, Pei-Ling L, György AZ, et al. Dysmorphism of urinary red blood cells: value in diagnosis. *Kidney Int*. 1989;36:1045-1049.
17. Hyodo T, Kumano K, Haga M, et al. Analysis of urinary red blood cells of healthy individuals by automated flow cytometer. *Nephron*. 1997;75:451-457.
18. Kohler H, Wandel E, Brunck B. Acanthocyturia: a characteristic marker for glomerular bleeding. *Kidney Int*. 1991;40:115-120.
19. Tomita M, Kitamoto Y, Nakayama M, et al. A new morphological classification of urinary erythrocytes for differential diagnosis of glomerular hematuria. *Clin Nephrol*. 1992;37:84-89.
20. Lettgen B, Wohlmuth A. Validity of G1-cells in the differentiation between glomerular and nonglomerular haematuria in children. *Pediatr Nephrol*. 1995;9:435-437.
21. Gyory AZ, Hawkins T, Ross M, et al. Clinical value of urine microscopy by manual and automated methods. *Lab Hematol*. 1998;4:211-216.