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Accuracy and Precision of Normal Level Control Serum Using Semi-Automatic and Fully Automatic Analyzer Methods for Urea and Uric Acid Parameters

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ABSTRACT

Background: Clinical laboratories need to be conducted with quality to support efforts to improve quality. Method validation in the laboratory is a quality control process aimed at ensuring that test results have good accuracy and precision so they can be trusted. Testing urea and uric acid levels is an important part of diagnosing kidney function disorders. Advances in clinical laboratory technology have impacted analytical method instruments, evolving from semi automatic to fully automatic. **Object:** The purpose of this study is to determine the accuracy and precision of normal level control serum for urea and uric acid parameters using semi automatic and fully automatic analyzers. **Method**: The type of research used in this study is comparative analytic with a cross-sectional approach. This study used commercial control serum at the normal level tested with both types of analyzers, semi automatic and fully automatic, then analyzed for inaccuracy and imprecision values. **Result:** The % bias value of the semi-automatic method on urea levels is 5.48% and uric acid levels is 4.73%. The % bias value of the fully automatic method on urea levels is 4.27% and uric acid levels is 3.43%. The CV% value of the semi-automatic method on urea levels is 6.30% and uric acid levels is 5.26%. The CV% value of the fully automatic analyzer method on urea levels is 4.86% and uric acid levels is 4.61%. **Conclusion:** Overall, both methods for testing urea and uric acid have good accuracy and precision, but the fully automatic method has better accuracy and precision.

Keywords: Accuracy, Precision, Urea, Uric Acid, Normal Serum Control, Semi Automatic, Fully Automatic

BACKGROUND

Clinical laboratories play a crucial role in examining biological specimens to establish diagnoses, assess health conditions, and monitor factors influencing public health. Approximately 60–70% of clinical decisions rely on laboratory results (Khotimah et al., 2022), emphasizing the importance of accuracy and reliability. To maintain service quality, laboratories must implement both Internal Quality Control (IQC) and External Quality Control (EQC) programs (Ulva, 2023). IQC is routinely conducted to prevent and control errors in the pre-analytical, analytical, and post-analytical phases (Siregar et al., 2018), including reagent testing, calibration, and evaluation of the accuracy and precision of laboratory results (Fadhilah, 2020).

To ensure accuracy and reliability, Quality Control (QC) procedures are implemented to evaluate laboratory performance and confirm that the quality management system operates effectively (Kusmiati et al., 2022). One key component of QC is control serum, which is used to monitor the precision and accuracy of daily tests. Control serum may be self-prepared or obtained commercially, with defined reference

values and tolerance limits based on the analytical method employed (Palentin et al., 2024). The validation of a laboratory method is determined by two primary parameters: accuracy, referring to the closeness of results to the true value, and precision, referring to the consistency of repeated measurements under the same conditions (Apriliana et al., 2019). Errors during testing may be random or systematic, both of which can significantly affect the reliability of laboratory outcomes (Kusmiati et al., 2022).

In clinical chemistry testing, instruments such as semi-automatic and fully automatic analyzers have become essential for improving laboratory efficiency and quality. Both systems operate on the same principle—measuring light intensity based on colorimetric reactions within the sample (Christiani et al., 2022). Although fully automatic analyzers offer higher efficiency and standardization, semi-automatic analyzers remain widely used due to their cost-effectiveness and ability to produce reliable results (Kumari et al., 2020; Chandana et al., 2023).

Clinical chemistry examinations cover various parameters, including kidney, liver, and cardiac function tests, as well as glucose, lipid profile, and electrolytes. Kidney function parameters such as urea and uric acid are categorized as Non-Protein Nitrogen (NPN) compounds, which assess renal excretory performance (Verdiansah, 2016; Fia et al., 2022). Urea is commonly analyzed using the enzymatic GLDH method (Susilawati & Sudrajat, 2024), while uric acid is determined using the uricase enzymatic method via photometric measurement (Martsiningsih & Otnel, 2016).

Previous studies have shown no significant difference between semi-automatic and fully automatic analyzers for various biochemical parameters, including urea, total cholesterol, triglycerides, SGOT, and SGPT (Kumari et al., 2020; Chandana et al., 2023). This indicates that semi-automatic analyzers can serve as an efficient and economical alternative to maintain laboratory quality. Therefore, this study aims to analyze the accuracy and precision of normal-level control serum using semi-automatic and fully automatic analyzers for urea and uric acid parameters.

METHOD

This study employed a comparative analytical design with a cross-sectional approach to evaluate the accuracy and precision of normal-level control serum for urea and uric acid parameters using semi-automatic and fully automatic analyzers. The research was conducted at Farmalab Clinical Laboratory from November 2024 to June 2025, utilizing 80 control serum samples (assayed, normal level) from the same batch number, collected over 20 working days. Sampling was conducted using purposive sampling, selecting laboratories equipped with both analyzer types.

Primary data were obtained through direct measurement, and the accuracy (compared with reference values) and precision (calculated from the coefficient of variation) were recorded. Data analysis was performed using descriptive and analytical statistics in Microsoft Excel to compare results between the two methods. This study was approved by the Health Research Ethics Committee of Poltekkes Kemenkes Surabaya, under approval number EA/3421/KEPK-Poltekkes_Sby/V/2025.

RESULT AND DISCUSSION

Control serum is used to monitor the accuracy and consistency of laboratory test results, ensuring that patient examination outcomes are reliable. The true value listed in the insert kit serves as the reference or gold standard, established by the manufacturer as the target value of the analyte contained in the control serum. This value is used to evaluate the accuracy and precision of laboratory measurements.

In this study, the control serum used was MTD Diagnostics Chemistry Control N (10 × 5 mL), Lot 70497801, with an expiration date of September 30, 2026. Table 1 presents the true values and acceptable ranges for each parameter

Table 1.

True Values and Reference Ranges Based on the Insert Kit.

Parameter	True Value (mg/dL)	1SD	Acceptable Range (± 3SD)
Urea	38.00	2.53	30.41 - 45.59
Uric Acid	4.51	0.30	3.61-5.41

Based on the measurement results of the normal control serum for the urea parameter using both semi-automatic and fully automatic analyzers, a total of 40 data points were obtained. These data were divided into two groups, consisting of 20 measurements from each analyzer type. Table 2 presents the measurement results of the urea parameter obtained from both methods.

Table 2.

Measurement results of normal control serum for the urea parameter using semi-automatic and fully automatic analyzers

Day	True Value	Semi automatic analyzer (mg/dL)	True Value	Fully automatic Analyzer (mg/dL)
1	38.00	34.45	38.00	38.41
2	38.00	37.45	38.00	37.64
3	38.00	40.45	38.00	39.06
4	38.00	38.95	38.00	36.49
5	38.00	33.17	38.00	38.25
6	38.00	37.24	38.00	42.13
7	38.00	35.74	38.00	37.22
8	38.00	37.88	38.00	39.71
9	38.00	35.95	38.00	40.35
10	38.00	36.81	38.00	36.11
11	38.00	38.31	38.00	38.46
12	38.00	36.59	38.00	40.41
13	38.00	34.67	38.00	36.75
14	38.00	37.02	38.00	38.80
15	38.00	33.60	38.00	40.71

Day	True Value	Semi automatic analyzer (mg/dL)	True Value	Fully automatic Analyzer (mg/dL)
16	38.00	41.30	38.00	43.36
17	38.00	40.87	38.00	37.82
18	38.00	38.09	38.00	38.02
19	38.00	34.67	38.00	40.06
20	38.00	35.10	38.00	40.73

Based on the measurement results of the normal control serum for the uric acid parameter using both semi-automatic and fully automatic analyzers, a total of 40 data points were obtained. These data were divided into two groups, consisting of 20 measurements from each analyzer type. Table 3 presents the measurement results of the uric acid parameter obtained from both methods.

Table 3.

Measurement results of normal control serum for the uric acid parameter using semi-automatic and fully automatic analyzers

Day	True Value	Semi automatic Analyzer (mg/dL)	True Value	Fully automatic Analyzer (mg/dL)
1	4.51	4.70	4.51	4.35
2	4.51	4.28	4.51	4.45
3	4.51	4.55	4.51	4.57
4	4.51	4.27	4.51	4.82
5	4.51	4.30	4.51	4.50
6	4.51	4.52	4.51	4.58
7	4.51	4.30	4.51	4.41
8	4.51	4.58	4.51	4.59
9	4.51	4.05	4.51	4.48
10	4.51	4.31	4.51	3.97
11	4.51	4.23	4.51	4.36
12	4.51	5.01	4.51	4.48
13	4.51	4.60	4.51	4.29
14	4.51	4.24	4.51	4.35
15	4.51	4.64	4.51	4.45
16	4.51	4.35	4.51	4.62

Day	True Value	Semi automatic Analyzer (mg/dL)	True Value	Fully automatic Analyzer (mg/dL)
17	4.51	4.31	4.51	4.87
18	4.51	4.66	4.51	4.81
19	4.51	4.22	4.51	4.43
20	4.51	4.17	4.51	4.71

The accuracy of the normal control serum measurement for the urea parameter using the semi-automatic and fully automatic analyzers was expressed as a bias value (inaccuracy), calculated as the difference between the measured result and the target (true) value of 38.00 mg/dL.

Table 4.

Accuracy values of normal control serum for the urea parameter using semi-automatic and fully automatic analyzers

Day	True Value	Semi automatic analyzer			Fully automatic Analyzer		
		Measured Value (mg/dL)	Bias (%)	Recovery (%)	Measured Value (mg/dL)	Bias (%)	Recovery (%)
1	38.00	34.45	9.33	90.67	38.41	1.08	101.08
2	38.00	37.45	1.45	98.55	37.64	0.95	99.05
3	38.00	40.45	6.44	106.44	39.06	2.79	102.79
4	38.00	38.95	2.49	102.49	36.49	3.97	96.03
5	38.00	33.17	12.71	87.29	38.25	0.66	100.66
6	38.00	37.24	2.01	97.99	42.13	10.87	110.87
7	38.00	35.74	5.95	94.05	37.22	2.05	97.95
8	38.00	37.88	0.32	99.68	39.71	4.50	104.50
9	38.00	35.95	5.39	94.61	40.35	6.18	106.18
10	38.00	36.81	3.14	96.86	36.11	4.97	95.03
11	38.00	38.31	0.81	100.81	38.46	1.21	101.21
12	38.00	36.59	3.70	96.30	40.41	6.34	106.34
13	38.00	34.67	8.77	91.43	36.75	3.29	96.71
14	38.00	37.02	2.57	97.43	38.80	2.11	102.11
15	38.00	33.60	11.58	88.42	40.71	7.13	107.13

Day	True Value	Semi automatic analyzer			Fully automatic Analyzer		
		Measured Value (mg/dL)	Bias (%)	Recovery (%)	Measured Value (mg/dL)	Bias (%)	Recovery (%)
16	38.00	41.30	8.69	108.69	43.36	14.11	114.11
17	38.00	40.87	7.56	107.56	37.82	0.47	99.53
18	38.00	38.09	0.24	100.24	38.02	0.05	100.05
19	38.00	34.67	8.77	91.23	40.06	5.42	105.42
20	38.00	35.10	7.64	92.36	40.73	7.18	107.18
Mean	38.00	36.92	5.48	97.14	39.02	4.27	102.70

Based on Table 4, the measurement results of the normal control serum for urea show that the bias (%) values are within the acceptable range of ±10%, and the recovery values fall between 95–105%. Therefore, both methods demonstrate good accuracy. The accuracy of the normal control serum measurement for the uric acid parameter using the semi-automatic and fully automatic analyzers is expressed as the bias value (inaccuracy), which represents the deviation between the measured result and the target (true) value of 4.51 mg/dL.

Table 5.

Accuracy values of normal control serum for uric acid using semi-automatic and fully automatic analyzers

Day	True Value	Semi automatic analyzer			Fully automatic Analyzer		
		Measured Value (mg/dL)	Bias (%)	Recovery (%)	Measured Value (mg/dL)	Bias (%)	Recovery (%)
1	4.51	4.70	4.21	104.21	4.35	3.55	96.45
2	4.51	4.28	5.10	94.90	4.45	1.33	98.67
3	4.51	4.55	0.89	100.89	4.57	1.33	101.33
4	4.51	4.27	5.32	94.68	4.82	6.87	106.87
5	4.51	4.30	4.66	95.34	4.50	0.22	99.78
6	4.51	4.52	0.22	100.22	4.58	1.55	101.55
7	4.51	4.30	4.66	95.34	4.41	2.22	97.78
8	4.51	4.58	1.55	101.55	4.59	1.77	101.77
9	4.51	4.05	10.20	89.80	4.48	0.67	99.33
10	4.51	4.31	4.43	95.57	3.97	11.97	88.03

Day	True Value	Semi automatic analyzer			Fully automatic Analyzer		
		Measured Value (mg/dL)	Bias (%)	Recovery (%)	Measured Value (mg/dL)	Bias (%)	Recovery (%)
11	4.51	4.23	6.21	93.79	4.36	3.33	96.67
12	4.51	5.01	11.09	111.09	4.48	0.67	99.33
13	4.51	4.60	2.00	102.00	4.29	4.88	95.12
14	4.51	4.24	5.99	94.01	4.35	3.55	96.45
15	4.51	4.64	2.88	102.88	4.45	1.33	98.67
16	4.51	4.35	3.55	96.45	4.62	2.44	102.44
17	4.51	4.31	4.43	95.57	4.87	7.98	107.98
18	4.51	4.66	3.33	103.33	4.81	6.65	106.65
19	4.51	4.22	6.43	93.57	4.43	1.77	98.23
20	4.51	4.17	7.54	92.46	4.71	4.43	104.43
Mean	4.51	4.41	4.73	97.88	4.50	3.43	99.88

Based on Table 5, the measurement results of the normal control serum for uric acid show that the bias (%) values fall within the acceptable range of ±10%, and the recovery values are within 95–105%. Therefore, both methods demonstrate good accuracy.

The precision of the normal control serum measurement for the urea parameter using the semi-automatic and fully automatic analyzers is expressed as the coefficient of variation (CV) representing imprecision, calculated using the formula (SD/mean) × 100%. Table 6 presents the CV values of the normal control serum for urea using both methods.

Table 6.

Precision values of normal control serum for urea using semi-automatic and fully automatic analyzers

Day	True Value	Semi automatic analyzer (mg/dL)	True Value	Fully automatic Analyzer (mg/dL)
1	38.00	34.45	38.00	38.41
2	38.00	37.45	38.00	37.64
3	38.00	40.45	38.00	39.06
4	38.00	38.95	38.00	36.49
5	38.00	33.17	38.00	38.25
6	38.00	37.24	38.00	42.13

Day	True Value	Semi automatic analyzer (mg/dL)	True Value	Fully automatic Analyzer (mg/dL)
7	38.00	35.74	38.00	37.22
8	38.00	37.88	38.00	39.71
9	38.00	35.95	38.00	40.35
10	38.00	36.81	38.00	36.11
11	38.00	38.31	38.00	38.46
12	38.00	36.59	38.00	40.41
13	38.00	34.67	38.00	36.75
14	38.00	37.02	38.00	38.80
15	38.00	33.60	38.00	40.71
16	38.00	41.30	38.00	43.36
17	38.00	40.87	38.00	37.82
18	38.00	38.09	38.00	38.02
19	38.00	34.67	38.00	40.06
20	38.00	35.10	38.00	40.73
Mean	38.00	36.92	38.00	39.02
SD		2.33		1.89
CV%		$\frac{2.33}{36.92} \times 100\%$		$\frac{1.89}{39.02} \times 100\%$
		6.30 %		4.86 %

Based on Table 6, both methods demonstrated good precision, as the CV% values were below the maximum allowable limit of 8%. The semi-automatic analyzer showed a mean value of 36.92 mg/dL, with an SD of 2.33 and a CV% of 6.30%, while the fully automatic analyzer showed a mean of 39.02 mg/dL, with an SD of 1.89 and a CV% of 4.86%.

The mean value for the urea parameter was 38.00 mg/dL, with a standard deviation (SD) of 2.53, as stated in the insert kit. This baseline value was used as a reference in constructing the Levey–Jennings chart to determine the upper and lower control limits. Table 7 presents the baseline values for these limits.

Table 7.

Upper and lower control limits for the urea parameter

Base Line	Value (mg/dL)
+ 3SD (38 + (3 x 2.53)	45,59
+ 2SD (38 + (2 x 2.53)	43,06
+ 1SD (38 + (1 x 2.53)	40,53
- 1SD (38 - (1 x 2.53)	35,47
- 2SD (38 - (2 x 2.53)	32,94
- 3SD (38 - (3 x 2.53)	30,41

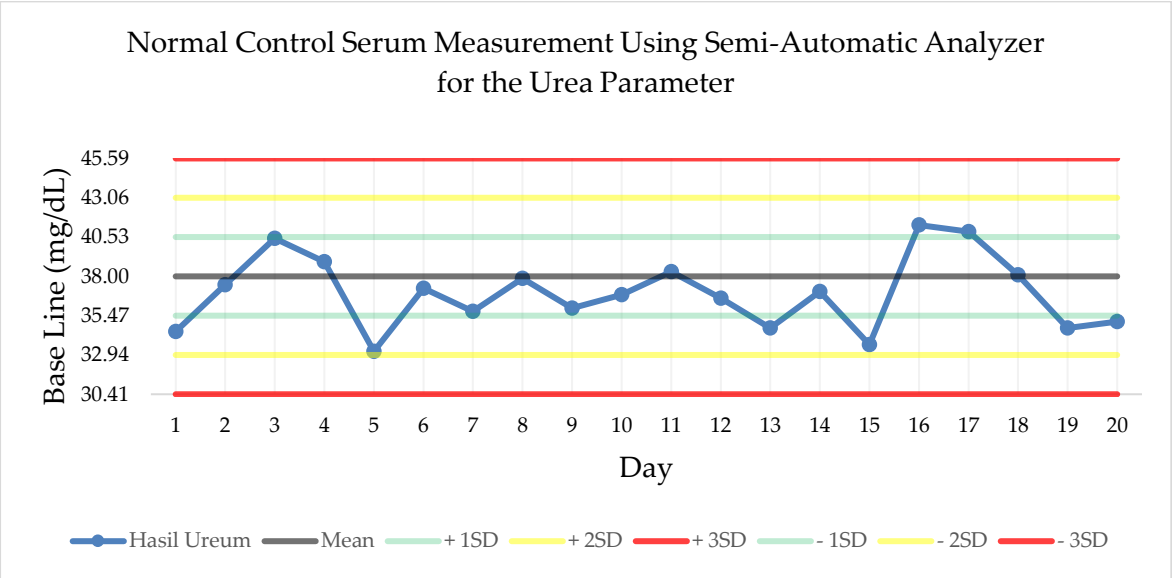

Figure 1. Levey–jennings chart for normal control serum measurement of urea using the semi-automatic analyzer

Based on Figure 1, the Levey–Jennings chart following Westgard rules for 20 repetitions of normal control serum measurements using the semi-automatic analyzer for the urea parameter showed no data points outside the ±2SD limits, indicating that the test results were stable and acceptable.

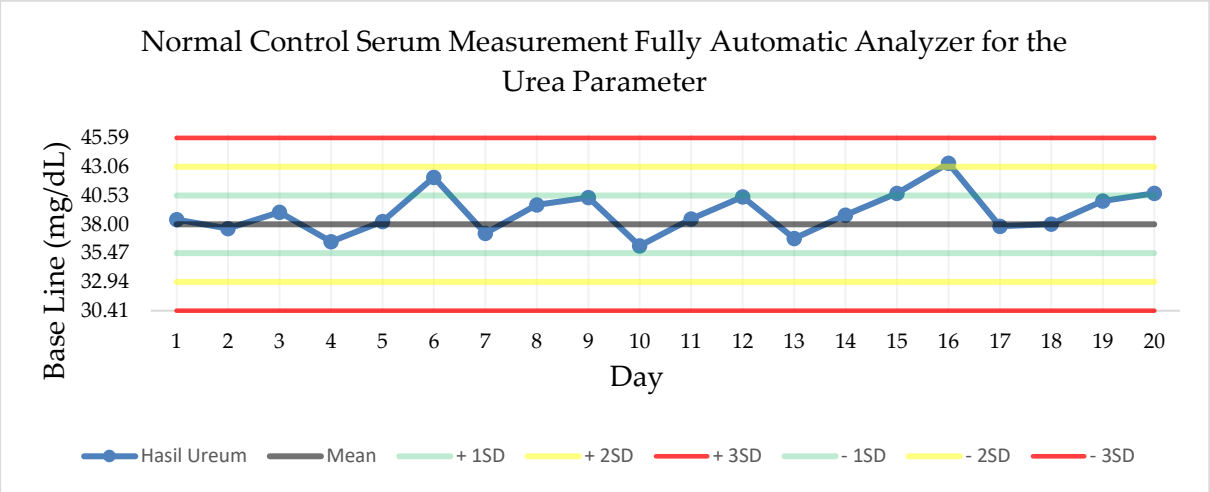

Figure 2. Levey–jennings chart for normal control serum measurement of urea using the fully automatic analyzer

Based on Figure 2, the Levey–Jennings chart following Westgard rules for the fully automatic analyzer showed that among 20 repetitions of the normal control serum measurement for the urea parameter, one result on day 16 fell outside the ±2SD warning limits. However, this value remained within the ±3SD range, indicating that the result was still acceptable.

In this study, the precision of normal control serum measurements for the uric acid parameter using both semi-automatic and fully automatic analyzers was expressed as the coefficient of variation (CV), representing imprecision. Imprecision was calculated by dividing the mean concentration of the control serum by its standard deviation (SD) and multiplying by 100%.

Table 8.

Precision Values of Normal Control Serum for Uric Acid Using Semi-Automatic and Fully Automatic Analyzers

Day	True Value	Semi automatic Analyzer (mg/dL)	True Value	Fully automatic Analyzer (mg/dL)
1	4.51	4.70	4.51	4.35
2	4.51	4.28	4.51	4.45
3	4.51	4.55	4.51	4.57
4	4.51	4.27	4.51	4.82
5	4.51	4.30	4.51	4.50
6	4.51	4.52	4.51	4.58
7	4.51	4.30	4.51	4.41
8	4.51	4.58	4.51	4.59
9	4.51	4.05	4.51	4.48
10	4.51	4.31	4.51	3.97
11	4.51	4.23	4.51	4.36

Day	True Value	Semi automatic Analyzer (mg/dL)	True Value	Fully automatic Analyzer (mg/dL)
12	4.51	5.01	4.51	4.48
13	4.51	4.60	4.51	4.29
14	4.51	4.24	4.51	4.35
15	4.51	4.64	4.51	4.45
16	4.51	4.35	4.51	4.62
17	4.51	4.31	4.51	4.87
18	4.51	4.66	4.51	4.81
19	4.51	4.22	4.51	4.43
20	4.51	4.17	4.51	4.71
Mean	4.51	4.41	4.51	4.50
SD		0.23		0.20
CV (%)		$\frac{0.23}{4.41} \times 100\%$		$\frac{0.20}{4.50} \times 100\%$
		5.26 %		4.61 %

Based on Table 8, the measurement results of the normal control serum for the uric acid parameter showed that the semi-automatic analyzer had a mean of 4.41 mg/dL, SD of 0.23, and CV of 5.26%, while the fully automatic analyzer had a mean of 4.50 mg/dL, SD of 0.20, and CV of 4.61%. Both methods demonstrated imprecision values (CV%) below the maximum limit of 6%, indicating good precision.

According to the insert kit, the uric acid parameter had a mean of 4.51 mg/dL and an SD of 0.30, which served as the baseline for constructing the Levey–Jennings chart to determine the maximum and minimum control limits, as presented in Table 9.

Table 9.

Maximum and Minimum Limits for the Uric Acid Parameter

Base Line	Nilai (mg/dL)
+ 3SD (4,51 + (3 x 0,30)	5,41
+ 2SD (4,51 + (2 x 0,30)	5,11
+ 1SD (4,51 + (1 x 0,30)	4,81
- 1SD (4,51 - (1 x 0,30)	4,21
- 2SD (4,51 - (2 x 0,30)	3,91
- 3SD (4,51 - (3 x 0,30)	3,61

The measurement results of the normal control serum for the uric acid parameter showed a +3SD limit of 5.41 and a −3SD limit of 3.61; a +2SD limit of 5.11 and a −2SD limit of 3.91; as well as a +1SD limit of 4.81 and a −1SD limit of 4.21. These data were then plotted on a

Levey–Jennings chart following the Westgard rules, as illustrated in Figure 3.

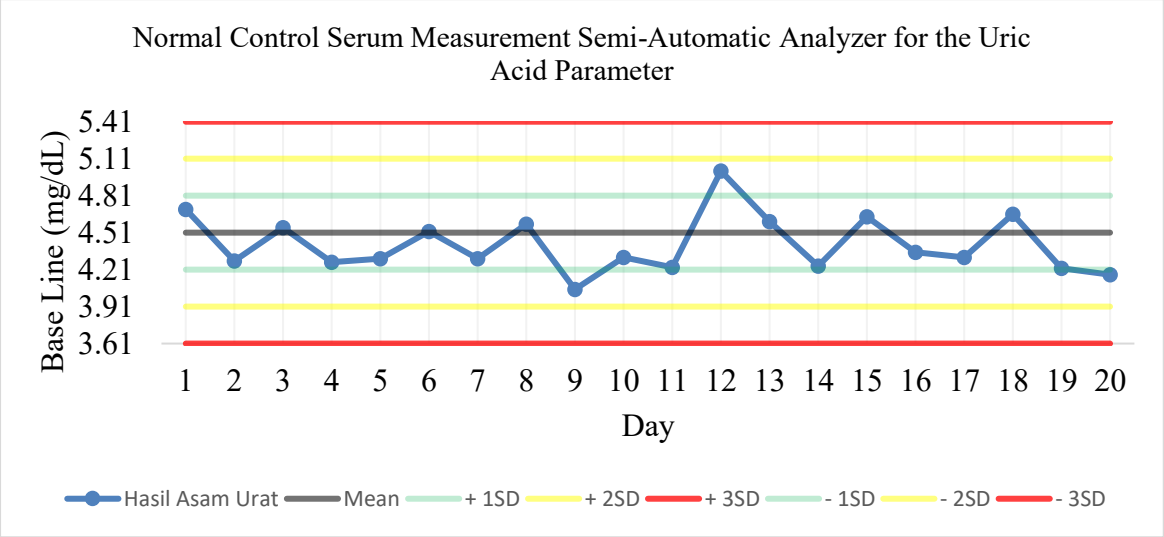

Figure 3. Levey–Jennings chart of normal control serum measurement for uric acid using the semi-automatic analyzer

Based on Figure 3, the Levey–Jennings chart following the Westgard rules for the measurement of normal control serum for the uric acid parameter using the semi-automatic analyzer (20 repetitions) showed that no results exceeded the ±2SD warning limits, indicating stable and acceptable performance. Meanwhile, the measurement results of the normal control serum for uric acid using the fully automatic analyzer were plotted on a Levey–Jennings chart applying the Westgard rules, with the mean and standard deviation values taken from the insert kit, as shown in Figure 4.

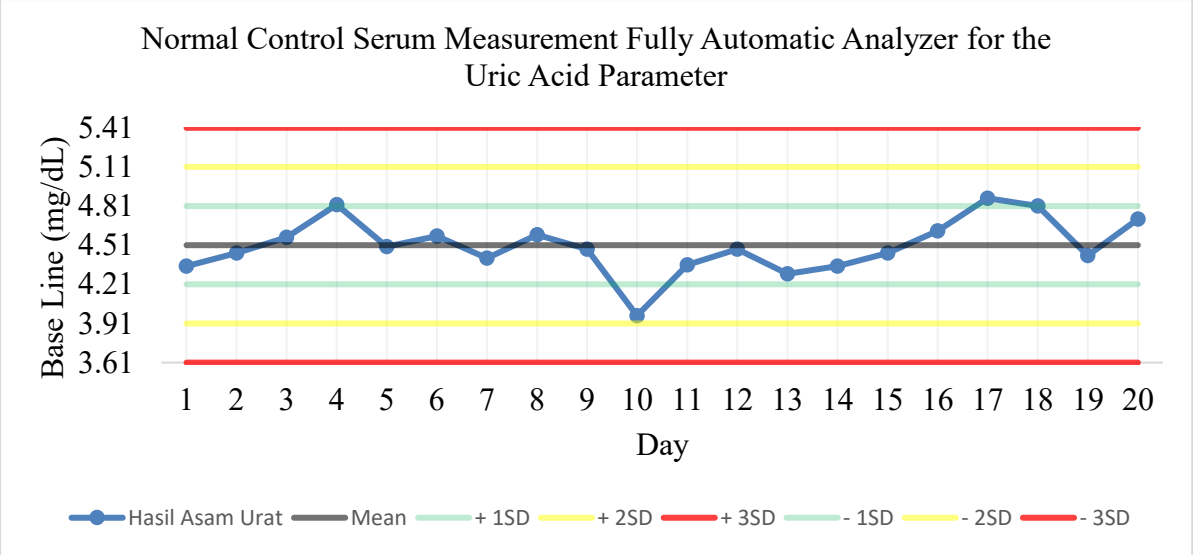

Figure 4. Levey–Jennings chart of normal control serum measurement for uric acid using the fully automatic analyzer

Based on Figure 4, the Levey–Jennings chart following the Westgard rules for the measurement of normal control serum for the uric acid parameter

using the fully automatic analyzer (20 repetitions) showed that all results were within the ±2SD warning limits, indicating stable and acceptable performance.

Discussion

This study was conducted over 20 working days, producing 80 data points from urea and uric acid measurements. A commercially assayed normal-level control serum was used. The instruments utilized were the Biobase Clinical Analyzer BK-200 for the fully automatic analyzer and the Microlab 300 for the semi-automatic analyzer.

Accuracy represents the closeness of a test result to the true value and is measured by the bias percentage (d%) from quality control results. Precision reflects the consistency of repeated measurements; a lower CV% indicates higher precision and reliability of the analytical method or instrument (Siregar et al., 2018).

According to Table 4, the semi-automatic analyzer showed a bias of 5.48% and a recovery of 97.14%, while the fully automatic analyzer showed a bias of 4.27% and a recovery of 102.70%. Both are within acceptable accuracy limits (bias ±10% and recovery 95–105%), although the fully automatic analyzer demonstrated slightly better accuracy with a smaller bias and recovery closer to 100%. Moreover, this method provides greater consistency due to automated processing, minimizing human error, though it requires higher maintenance costs (Chandana et al., 2023).

Table 5 shows that for uric acid, the semi-automatic analyzer had a bias of 4.73% and recovery of 97.88%, whereas the fully automatic analyzer had a bias of 3.43% and recovery of 99.88%. Both were within acceptable accuracy limits, but the fully automatic analyzer was more accurate. Systematic errors may arise from suboptimal calibration, standards, or instruments and can be minimized through routine calibration and maintenance. Proper pipetting technique — including using sterile tips and maintaining a vertical pipette position — is also essential to ensure accuracy (Santoso, 2015; Ewald, 2010).

According to the Ministry of Health (Permenkes), the maximum allowable CV% for urea testing is 8%. The semi-automatic analyzer had a CV% of 6.30%, while the fully automatic analyzer showed 4.86%, both within acceptable limits. The smaller CV% of the fully automatic analyzer indicates higher precision, supported by a lower standard deviation (SD) of 1.89 compared to 2.33 for the semi-automatic method (Fadhilah, 2020). Precision relates to random errors, which may arise from variations in sample, temperature, reagents, calibration, or technique. Good precision is reflected in the Levey–Jennings chart, where results cluster closely around the mean line (Apriansyah et al., 2021). In Figure 1, one data point on day 16 was outside ±2SD but still within ±3SD (Westgard 12S rule), meaning results were acceptable but required attention. In contrast, Figure 2 shows that all results were within ±2SD (Aditia et al., 2024).

Additionally, clogged probes may affect test accuracy; residue or particulate buildup can obstruct pipetting and lead to erroneous results (Imai et al., 2008).

For uric acid testing, the maximum CV% set by Permenkes is 6%. The semi-automatic analyzer had a CV% of 5.26%, while the fully automatic analyzer had 4.61%, both within acceptable precision limits (Siregar et al., 2018). The lower CV% and smaller SD (0.20 vs. 0.23) indicate better precision for the fully automatic analyzer. This consistency was also confirmed by the Levey–Jennings chart, where all results were within ±2SD, reflecting stable, accurate, and reliable analytical performance (Apriansyah et al., 2021).

Overall, both the semi-automatic and fully automatic analyzers demonstrated good accuracy and precision for urea and uric acid measurements, with the fully automatic analyzer showing slightly

superior performance. These findings align with Kumari et al. (2020) and Chandana et al. (2023), who reported no significant difference between the two methods across various clinical chemistry parameters. Minor discrepancies may result from factors such as sample quality, instrument stability, temperature fluctuations, reagent variation, calibration frequency, operator technique, and procedural elements like pipetting, mixing, and incubation time. Furthermore, irregular or inaccurate calibration and pipetting errors during control preparation can contribute to systematic or random errors, underscoring the need for routine calibration and result verification.

CONCLUSION

The fully automatic analyzer demonstrated higher accuracy and precision for both urea and uric acid parameters compared to the semi-automatic analyzer. Based on the Levey–Jennings chart, all measurement results were within acceptable control limits, indicating that both analytical methods produced reliable and valid results.

CONFLICT OF INTEREST

The authors declare no competing interests.

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