Method Verification of the Caretium XC-A30 Automated Erythrocyte Sedimentation Rate Analyser for Erythrocyte Sedimentation Rate

Soemwit Khongwichit¹, Menapha Saelim², Yanisa Na-Songkhla², Hansuk Buncherd¹, Chawadee Nonparatana², Kanitta Srinoun¹

¹ Faculty of Medical Technology, Prince of Songkla University, Songkhla, Thailand
² Department of Pathology, Faculty of Medicine, Prince of Songkla University, Songkhla, Thailand

To cite this article: Khongwichit S, Saelim M, Na-Songkhla Y, Buncherd H, Nopparatana C, Srinoun K. Method verification of the Caretium XC-A30 automated erythrocyte sedimentation rate analyser for erythrocyte sedimentation rate. Malays J Med Sci. 2022;29(5):39–47. https://doi.org/10.21315/mjms2022.29.5.5

To link to this article: https://doi.org/10.21315/mjms2022.29.5.5

Abstracts

Background: The erythrocyte sedimentation rate (ESR) analyser is widely used in haematological testing. In addition to the Westergren method, new automatic methods for ESR measurements have been developed. We aimed to study the reliability, precision, accuracy and stability of the Caretium XC-A30 automated ESR analyser.

Methods: Ethylenediamine tetraacetic acid (EDTA)-treated blood samples were analysed via the Caretium XC-A30 automated ESR analyser and the Westergren method to compare accuracy. Precision was assessed using control samples and patient samples were classified into three groups—low, medium and high—according to their rates of sedimentation. Moreover, a stability test was performed.

Results: The correlation coefficient of the results of the Caretium XC-A30 and Westergren analyses was 0.97. The correlation coefficient of ESR values obtained from the two methods assessed in the low, medium and high groups were $r = 0.80$, $r = 0.68$ and $r = 0.74$, respectively. The coefficient of variation of within-run (%CVw) and between-run (%CVb), with replicates performed with commercial controls samples, were 7.54% and 8.04% for the normal control and 4.68% and 3.50% for abnormal control, respectively. The %CVw obtained with patient samples in the low, medium and high groups were 10.68%, 13.13% and 4.45%, respectively. The Caretium XC-A30 measurements were stable for up to 24 h when samples were stored at 4 °C.

Conclusion: The Caretium XC-A30 ESR analyser proved to be a suitable instrument for routine analysis of ESR.

Keywords: erythrocyte sedimentation rate, automated ESR analyser, method verification

Introduction

The erythrocyte sedimentation rate (ESR) test is one of the most commonly presented haematology laboratory tests (1–4). The process of obtaining the ESR is described as three steps consisting of red blood cell (RBC) aggregation into rouleaux formations, followed by their precipitation, sedimentation and erythrocyte packaging (5, 6). Although ESR is usually used to investigate the acute phase response in inflammation (7, 8), its measurement is commonly affected by RBC shape, RBC size, RBC number, haematocrit and plasma protein concentration and especially by temperature and fibrinogen (6, 7). Currently, more specific inflammation testing has been reported; however, ESR remains useful in the diagnosis and follow-up of clinical conditions, such as rheumatoid arthritis (6, 7, 9) and Hodgkin lymphoma (10).
The standard method for ESR measurement is the Westergren method, as recommended by the International Council for Standardisation in Haematology (ICSH) (11, 12). This method uses a dilution of four volumes of blood to one volume of sodium citrate (13) and measures the distance erythrocytes fall after 1 h in mm (12, 14). However, the Westergren method has several well-described limitations for routine laboratory practice, including blood volume requirements and lengthy analysis time (> 1 h) (7, 15–17). To address these issues, a number of novel, modified semi-automated and alternate methods for ESR detection have been developed. Alternate ESR methods employ different principles than those of the Westergren method, such as photometric aggregometry or centrifugation (12) and these methods include ESR STAT PLUS (HemaTechnologies, Lebanon, NJ) (18), iSED (Alcor Scientific Inc., Smithfield, RI) or Test 1 (Alifax S.p.A., Polverara, Italy) (22–25). These methods perform the rouleaux formation step, the initial stage of ESR testing, resulting in a reduction in analysis time. Several automations, established by the conventional Westergren method, were introduced by using whole blood diluted with citrate, such as the StaRRsed (Mechatronics, Zwaag, the Netherlands) analyser (20, 26), Sediplast ESR (Polymedco, Cortlandt Manor, NY) (27) or the SEDIsystem (Becton Dickinson, Meylan Cedex, France) (28). However, the results obtained via these different methods can differ from the standard Westergren method (1, 12).

Caretium XC-A30 Automated ESR Analyser

Caretium XC-A30 is an automated analyser that measures ESR using infrared photometry. The patients’ whole blood samples were drawn into IMPROVACUTER® ESR tubes that contained sodium citrate (3.2%) as the anticoagulant. In this way, citrate diluted blood (four volumes of blood to one volume of citrate) was achieved. The samples were mixed at least five times. To minimise the turnaround time, the sedimentation was measured by using an infrared optical sensor after 30 min. The results are then given in mm and were automatically standardised into 60 min measurement times using values obtained at 18 °C according to the manufacturer.

Precision Study

Within-run and between-run precision were determined by analysing normal and abnormal ESR ranges obtained using a commercially available control, the Liquichek™ Sedimentation Rate Control (Bio-Rad Laboratories, Inc.), which is composed of stabilized human whole blood. Using the Clinical Laboratory Standards Institute (CLSI) protocol (29, 30), within-run precision was assessed by performing 20 consecutive measurements. Between-run precision was analysed by processing the manufacturer’s
control material three times daily for 20 days. Additionally, within-run precision was assessed by performing 20 replicate measurements of three patient samples in each of the low (< 20 mm), middle (21 mm–80 mm) and high (> 80 mm) ESR values groups. Means, standard deviations and coefficient of variations (CVs) were calculated. Imprecision was calculated as the CVs of within-run (%CV<sub>w</sub>) and between-run (%CV<sub>b</sub>) precision. %CV<sub>3</sub> and %CV<sub>5</sub> were used for the calculation of total imprecision (CV<sub>t</sub>) using the following equation:

\[
CV_t = \sqrt{(CV_{3})^2 + (CV_{5})^2}
\]

**Method Comparisons Study**

A total of 125 samples were chosen randomly and then used for method comparison. Samples were investigated in parallel by the Westergren and Caretium XC-A30 automated methods (31). Passing-Bablok linear regression analysis was used to determine the degree of correlation between the results of the Westergren methods and those of the Caretium XC-A30 automated ESR analyser and Bland-Altman difference plots were used to assess absolute differences. Correlation coefficients and biases for samples in the low (< 20 mm), middle (20 mm–60 mm) and upper third (> 60 mm) of the analytical range were determined (12, 14). To compare the two methods, data distribution was assessed by the Shapiro-Wilk test. Spearman’s rank correlations (r) were used to compare results between manual methods and the automated ESR analyser. Statistical significance was assumed to be \( P < 0.05 \). The MedCalc software free trial version was used in the evaluations.

**Sample Stability**

Sample stability analysis was performed randomly on 22 samples. The samples were then divided into aliquots and stored at either room temperature (RT) or 4 °C. Samples stored at 4 °C were then allowed to return to room temperature before re-testing. ESR measurements were performed by the Caretium XC-A30 automated ESR analyser at 4 h, 6 h, 8 h and 24 h after collection. The results were compared using a parametric paired t-test. Values of \( P < 0.05 \) were accepted as statistically significant (SPSS 23.0, SPSS Inc., Chicago, Ill., USA).

**Results**

**Method Comparisons Study**

The ESR results measured by using the Caretium XC-A30 analysers were compared with the standard Westergren methods. The obtained Spearman’s rank correlation (r) was 0.97 (95% confidence interval [CI]: 0.96, 0.98; \( P < 0.0001 \)). Passing-Bablok linear regression showed a regression equation \( y = 1.15 + 0.80x \), \( y \)-intercept of 1.15 (95% CI: 0.05, 2.44) and slope of 0.80 (95% CI: 0.76, 0.83) (Figure 1). Bland-Altman difference plot analysis revealed a positive mean bias of 8.13 (95% CI: 5.83, 10.43) (Figure 2). We classified the results into subgroups as follows: low (< 20 mm), middle (20 mm–60 mm) and upper third (> 60 mm). The results of the Passing-Bablok linear regression and Bland-Altman difference analyses are shown in Table 1. Measurements obtained by the methods from samples in the lower third of the analytical range presented a good correlation across the two methods (r = 0.80; \( P < 0.0001 \)), but a moderate correlation was found with samples from the middle and upper third of the analytical range (r = 0.68; \( P < 0.0001 \) and r = 0.74; \( P < 0.0001 \), respectively). The Bland-Altman difference plot exhibited a significant increase in the differences between the two tests at ESR values > 60 mm with an observed mean difference of 16.4 mm (95% CI: 11.18, 21.70).
Figure 1. Correlation of the Caretium XC-A30 analyser and the Westergren methods

Table 1. Comparison statistics at the lower, middle, and upper third of the analytical range

| Analytical range | N   | Bias (95% CI)  | Correlation coefficient (r) | Intercept (95% CI) | Slope (95% CI) |
|------------------|-----|----------------|----------------------------|-------------------|----------------|
| ESR (< 20 mm)    | 44  | 1.35 (0.14, 2.57) | 0.80                       | 2.83 (0.96–3.75)  | 0.67 (0.58–0.79) |
| ESR (20 mm–60 mm)| 41  | 7.3 (3.83, 10.78) | 0.68                       | 4.23 (–3.31–9.56) | 0.71 (0.56–0.92) |
| ESR (> 60 mm)    | 40  | 16.4 (11.18, 21.70)| 0.74                       | 16.33 (1.43–34.5) | 0.67 (0.50–0.81) |

Precision

The CV values for the within-run and between-run precision analysis were 7.54% and 8.04% for the normal control and, 4.68% and 3.50% for the abnormal control, respectively. The CV values for the total precisions of the normal and abnormal commercial controls were 11.02% and 5.84%, respectively (Table 2). The CV values for the within-run precision analyses of patient samples at low, medium, and high were 10.68%, 13.13%, and 4.45%, respectively (Table 3).

Table 2. Within-run and between-run precision analysis with commercial controls

|          | Mean ± SD (mm) | CV (%) | Range (mm) |
|----------|----------------|--------|------------|
| Normal control (lot 27841) |                |        |            |
| Within-run precision | 4.39 ± 0.33 | 7.54   | 3.91–5.92  |
| Between-run precision | 5.19 ± 0.42 | 8.04   | 4.43–5.93  |
| Total precision     |               | 11.02  |            |
| Abnormal control (lot 27841) |            |        |            |
| Within-run precision | 44.86 ± 2.10 | 4.68   | 41.47–57.83|
| Between-run precision | 50.50 ± 1.77 | 3.50   | 41.17–53.67|
| Total precision     |               | 5.84   |            |
The results of the stability studies of the Caretium XC-A30 automated ESR analyser are shown in Table 4. The specimens were stored at 4 °C. The ESR results obtained using samples stored at 4 °C did not change significantly after 24 h of collection; whereas, the ESR results of the samples at room temperature diminished significantly at 24 h.

Table 4. Evaluation of stability study

| Samples stored at RT | Fresh (n = 22) | 4 h (n = 22) | 6 h (n = 22) | 8 h (n = 22) | 24 h (n = 22) |
|---------------------|---------------|-------------|-------------|-------------|--------------|
| Mean (SD) (mm)      | 8.98 (5.25)   | 8.66 (4.22) | 9.18 (4.22) | 8.68 (5.20) | 4.83 (1.97)  |
| Mean of differences (mm) | 0.32       | −0.19       | 0.30        | 4.15        |
| 95% CI              | −2.1, 2.75    | −5.19, 1.21 | −2.36, 2.96 | 2.11, 6.20  |
| P-value             | 0.792         | 0.873       | 0.500       | 0.000*      |
| Mean (SD) (mm)      | 8.62 (5.15)   | 10.47 (5.83)| 9.85 (5.95) | 9.95 (6.13) | 10.19 (5.81) |
| Mean of differences (mm) | −1.85      | −1.23       | −1.33       | −1.57       |
| 95% CI              | −4.64, 0.94   | −4.06, 1.59 | −4.21, 1.55 | −4.36, 1.22 |
| P-value             | 0.191         | 0.386       | 0.358       | 0.266       |

Notes: ESR values are expressed as mean (SD); *There is a significant difference (P < 0.05) from the fresh ESR result.

Discussion

The ESR test is a commonly used laboratory test for evaluating acute phase response inflammation (8). Despite the Westergren method being the gold standard method for the measurement of ESR, this method is time-consuming, requires a large volume of blood samples, and is laborious (7, 15–17). To overcome these issues, several automated systems are now available for ESR measurement (12). According to the ICSH classification guidelines, these novel technologies are characterised as modified Westergren methods, when they feature some modifications to the Westergren methodology and alternate ESR methods for those created using different methodological principles, such as centrifugation or photometric rheology (20). Caretium XC-A30 is a newly established, automated alternate ESR analyser. It is a small bench-top equipment (40 cm × 30 cm × 20 cm) that has been established for small to medium-sized laboratories. This method is based on infrared photometric aggregometry, which produces results in 30 min resulting in a reduction in analysis time. Caretium XC-A30 has also been designed to use less blood volume. To our knowledge, this study is the first to report that Caretium XC-A30 shows satisfactory precision characteristics and comparability with the referenced standard Westergren method.

Herein, we demonstrated good precision of Caretium XC-A30 with commercial control samples at normal evaluated at normal levels than in modified Westergren ESR automation, StaRRsed (20) and Ves-Matic Cube 200 (32) but compared to evaluations obtained from other methods, evaluation using abnormal control levels resulted in a slight increase in imprecision. Based on similar determination techniques, the imprecision of Caretium XC-A30 with commercial control samples evaluated at both normal and abnormal levels was higher than those obtained with iSED (19) and Test-1 analyser (25).
According to CLSI H2-A4 guidelines, acceptable performance limits are described for ESR results and CV (%) values between 10.88 and 38.88, for different ESR values are considered acceptable performance limits (8). In our study, we assessed patient samples using low, medium and high ESR values, with 20 replicate measurements. The within-run precisions were 10.68%, 13.13% and 4.45% in the low, medium and high ESR groups, respectively. Caretium XC-A30 seems to have precisions within acceptable performance limits described in the guidelines. The evaluated patient sample ESR levels were similar to already reported data for iSED and Ves-Matic cube 200, with higher CVs observed at low and medium ESR levels (19–21). Interestingly, our data demonstrated lower within-run decreasing CVs at the low and high ESR levels than those described in previously reported data (19–21, 25).

Our study comparing the performance of the Caretium XC-A30 and the Westergren method revealed a good correlation. The overall correlation coefficient was 0.97 (95% CI: 0.96, 0.98; P < 0.0001). A significant mean difference of 8.13 (95% CI: 5.83, 10.43) was detected in this study. In the subgroup analysis, there was a good correlation between Caretium XC-A30 and the Westergren method at ESR levels in a lower analytical range. A moderate correlation of the two analysers was found using samples evaluated at the middle and upper third of the analytical range. However, the measurements obtained from upper third of the analytical range showed a large mean bias of 16.4 mm (95% CI: 11.18, 21.70).

The accuracy of the overall correlation coefficient of our group was similar to that reported in the modified Westergren ESR principles, such as the SEDI system (7, 28) and StaRRsed (7). However, our result showed a higher correlation coefficient than those obtained with the Ves-Matic Cube 200 (7, 25, 32). The overall correlation coefficient was similar to those previously reported using the iSED (19, 20) and Test-1 analyser (25), of which are each alternate ESR measurement methods. Unlike the other methods, the results of subgroup analysis for ESR values obtained using the Caretium XC-A30 method have been reported to have a good or moderate correlation with the ESR values obtained from the standard Westergren methods. This result is even more obvious when evaluating the correlation coefficients per each ESR level group, including those within the upper third of the analytical range (18–22, 32). However, the ESR values within this higher analytical range obtained from the Caretium XC-A30 were significantly higher than those of the Westergren method, with a mean difference of 16.4 mm (95% CI: 11.18, 21.70), meaning that a patient could have high ESR if detected by Caretium XC-A30 and normal ESR if detected with the Westergren method, or vice versa, which could each possibly cause different clinical interpretations. These inconsistencies can be attributed to the principal differences of the two techniques and the difference in the timing of ESR measurements, as Caretium XC-A30 estimates ESR by kinetic assessment of rouleaux formation in the initial sedimentation phase, while the classical Westergren method measures ESR after all three phases of sedimentation.

A major limitation of Westergren ESR methods is the requirement to perform the test within 4 h from the time of sample collection when stored at room temperature (12). Caretium XC-A30 ESR results, when the specimens were stored in a refrigerator, did not change significantly after 24 h of collection but ESR results of room temperature samples declined significantly at 24 h. The reduction in sample ESR after 24 h has been described by other reports. They demonstrated that this reduction could depend on RBC swelling and the reduction in sialic acid within the RBC cell membranes (5, 33). Our results were similar to stability testing conducted in the Ves-Matic Cube 200 ESR experiment; (21, 25, 34), wherein the results obtained using the iSED and Test-1 analyser were stable at room temperature and 4 °C after 24 h of collection (20, 25).

In summary, the Caretium XC-A30 analyser provides accurate ESR measurements and demonstrates acceptable concordance with the gold standard Westergren method. However, the limitation of this accuracy study is that the sample size may not sufficiently reflect the results of all pathological ESR levels examined by this instrument. Hence, the need for subsequent studies with a larger number of samples should be conducted in order to reveal better accuracy. Additionally, the effects of interfering elements such as fibrinogen and paraprotein, which increase rouleaux formation, were not assessed in the study.
Conclusion

In conclusion, the Caretium XC-A30 analyser is a novel alternative ESR method providing rapid measuring time and precise and accurate determination of the ESR. The Caretium XC-A30 analyser offers advantages, including reliability, reduced sample volumes requirements and extended sample stability. However, at the upper third of the analytical range, the large mean bias difference between the Caretium XC-A30 analyser and Westergren method was remarkable; thus, the results should be interpreted with caution. Further studies assessing the impact of alternative ESR methods on the clinical investigation should be undertaken.

Acknowledgements

We thank the Department of Pathology, Faculty of Medicine, Prince of Songkla University and Meditop Co. Ltd. for kindly providing the ESR automation analysers (Caretium XC-A30) and reagents.

Ethics of Study

The study was approved by the Office of Human Research Ethics Committee, Faculty of Medicine, Prince of Songkhla University (REC 63-340-19-2)

Conflict of Interest

None.

Funds

None.

Authors’ Contributions

Conception and design: HB, CN, KS
Analysis and interpretation of the data: SK, KS
Drafting of the article: SK
Critical revision of the article for important intellectual content: KS
Final approval of the article: SK, MS, YN, HB, CN, KS
Provision of study materials or patients: MS, YN
Statistical expertise: CN, KS
Obtaining funding: KS

Original Article | ESR analyser for ESR detection

Correspondence

Associate Professor Dr Kanitta Srinoun
PhD (Mahidol University)
Faculty of Medical Technology,
Prince of Songkla University,
15 Kanjanavanit Rd., Hat Yai, Songkhla 90110,
Thailand.
Tel: 66 74 289118
Fax: 66 74 289101
E-mail: kanitta.s@psu.ac.th

References

1. Plebani M. Erythrocyte sedimentation rate: innovative techniques for an obsolete test? Clin Chem Lab Med. 2003;41(2):115–116. https://doi.org/10.1515/CCLM.2003.019
2. Plebani M, Piva E. Erythrocyte sedimentation rate: use of fresh blood for quality control. Am J Clin Pathol. 2002;117(4):621–626. https://doi.org/10.1309/QBI6-6FRR-DNWX-BKQ9
3. Horton S, Fleming KA, Kuti M, Looi LM, Pai SA, Sayed S, et al. The top 25 laboratory tests by volume and revenue in five different countries. Am J Clin Pathol. 2019;151(5):446–451. https://doi.org/10.1093/ajcp/ajy165
4. Grzybowski A, Sak J. A short history of the discovery of the erythrocyte sedimentation rate. Int J Lab Hematol. 2012;34(4):442–444. https://doi.org/10.1111/j.1751-553X.2012.01430.x
5. Perovic E, Bakovic L, Valcic A. Evaluation of Ves-Matic Cube 200—an automated system for the measurement of the erythrocyte sedimentation rate. Int J Lab Hematol. 2010;32(1 Pt 2):88–94. https://doi.org/10.1111/j.1751-553X.2008.01135.x
6. Brigden ML. Clinical utility of the erythrocyte sedimentation rate. Am Fam Physician. 1999;60(5):1443–1450.
7. Curvers J, Kooren J, Laan M, van Lierop E, van de Kerkhof D, Scharnhorst V, et al. Evaluation of the Ves-Matic Cube 200 erythrocyte sedimentation method: comparison with Westergren-based methods. Am J Clin Pathol. 2010;134(4):653–660. https://doi.org/10.1309/AJCPMEW6zBGQKJH
8. Koepke JA BB, Simson E. Reference and selected procedure for the erythrocyte sedimentation rate (ESR) test; approved standard. NCCLS Document H2-A4, 4th ed. Pennsylvania, USA: NCCLS; 2001:1–24.

9. Aletaha D, Smolen JS. Diagnosis and management of rheumatoid arthritis: a review. JAMA. 2018;320(13):1360–1372. https://doi.org/10.1001/jama.2018.13103

10. Eichenauer DA, Aleman BMP, Andre M, Federico M, Hutchings M, Illidge T, et al. Hodgkin lymphoma: ESOMO clinical practice guidelines for diagnosis, treatment and follow-up. Ann Oncol. 2018;29 (Suppl 4):iv19–iv29. doi:10.1093/annonc/mdy080

11. BMJ Publishing Group Ltd and Association of Clinical Pathologists. ICSH recommendations for measurement of erythrocyte sedimentation rate. International Council for Standardization in Haematology (expert panel on blood rheology). J Clin Pathol. 1993;46(3):198–203. https://doi.org/10.1136/jcp.46.3.198

12. Kratz A, Plebani M, Peng M, Lee YK, McCafferty R, Machin SJ, et al. ICSH recommendations for modified and alternate methods measuring the erythrocyte sedimentation rate. Int J Lab Hematol. 2017;39(5):448–457. https://doi.org/10.1111/ijlh.12693

13. Reference method for the erythrocyte sedimentation rate (ESR) test on human blood. Br J Haematol. 1973;24(5):671–673. https://doi.org/10.1111/j.1365-2141.1973.tb01693.x

14. Jou JM, Lewis SM, Briggs C, Lee SH, De La Salle B, McFadden S, et al. ICSH review of the measurement of the erythrocyte sedimentation rate. Int J Lab Hematol. 2011;33(2):125–132. https://doi.org/10.1111/j.1751-553X.2011.01302.x

15. Besson I, Kinder M, Jou JM, Vives Corrons JL. Evaluation of 3 automatic systems for measurement of the erythrocyte sedimentation rate. Sangre (Barc). 1995;40(2):103–107.

16. Von Boroviczeny KG, Böttiger LE, Bull BS, Chattas A, Dawson JB, Fukutake K, et al. Recommendation of measurement of erythrocyte sedimentation rate of human blood. Am J Clin Pathol. 1977;68(4):505–507. https://doi.org/10.1093/ajcp/68.4.505

17. Mahlangu JN, Davids M. Three-way comparison of methods for the measurement of the erythrocyte sedimentation rate. J Clin Lab Anal. 2008;22(5):346–352. https://doi.org/10.1002/jcla.20267

18. Shelat SG, Chacosky D, Shibutani S. Differences in erythrocyte sedimentation rates using the Westergren method and a centrifugation method. Am J Clin Pathol. 2008;130(1):127–130. https://doi.org/10.1309/E5R9P5YPHXFE3198

19. Lapic I, Milos M, Tosato F, Piva E, Zadro R, Rogic D, et al. Analytical validation of the iSED automated analyzer for erythrocyte sedimentation rate. Int J Lab Hematol. 2020;42(2):109–115. https://doi.org/10.1111/ijlh.13120

20. Schapkaitz E, RabuRabu S, Engelbrecht M. Differences in erythrocyte sedimentation rates using a modified Westergren method and an alternate method. J Clin Lab Anal. 2019;33(2):e22661. https://doi.org/10.1002/jcla.22661

21. Bogdaycioglu N, Yilmaz FM, Sezer S, Oguz E. Comparison of iSED and Ves-Matic Cube 200 erythrocyte sedimentation rate measurements with Westergren method. J Clin Lab Anal. 2015;29(5):397–404. https://doi.org/10.1002/jcla.21786

22. Sonmez C, Dogan OC, Kaymak AO, Akkaya N, Akin KO, Guntas G. Test-1 analyzer and conventional Westergren method for erythrocyte sedimentation rate: a comparative study between two laboratories. J Clin Lab Anal. 2018;32(5):e22384. https://doi.org/10.1002/jcla.22384

23. Hardeman MR, Levitus M, Pelliccia A, Bouman AA. Test 1 analyser for determination of ESR 1. Practical evaluation and comparison with the Westergren technique. Scand J Clin Lab Invest. 2010;70(1):21–25. https://doi.org/10.3109/00365510903365952

24. Hardeman MR, Levitus M, Pelliccia A, Bouman AA. Test 1 analyser for determination of ESR. 2. Experimental evaluation and comparison with RBC aggregometry. Scand J Clin Lab Invest. 2010;70(1):26–32. https://doi.org/10.3109/00365510903365960
25. Lapic I, Piva E, Spolaore F, Tosato F, Peloso M, Plebani M. Automated measurement of the erythrocyte sedimentation rate: method validation and comparison. *Clin Chem Lab Med.* 2019;57(9):1364–1373. https://doi.org/10.1515/cclm-2019-0204

26. Horsti J, Rontu R, Collings A. A comparison between the StaRRsed auto-compact erythrocyte sedimentation rate instrument and the Westergren method. *J Clin Med Res.* 2010;2(6):261–265. https://doi.org/10.4021/jocmr476w

27. Vennapusa B, De La Cruz L, Shah H, Michalski V, Zhang QY. Erythrocyte sedimentation rate (ESR) measured by the streeck ESR-auto plus is higher than with the Sediplast Westergren method: a validation study. *Am J Clin Pathol.* 2011;135(3):386–390. https://doi.org/10.1309/AJCP48YXBDGTGXEV

28. AlFadhli SM, Al-Awadhi AM. Comparison of erythrocyte sedimentation rate measurement by the automated SEDIsystem and conventional Westergren method using the Bland and Altman statistical method. *Med Princ Pract.* 2005;14(4):241–244. https://doi.org/10.1159/000085742

29. Clinical and Laboratory Standards Institute (CLSI). *Evaluation of precision performance of clinical chemistry devices; approved guideline (EP5-A).* Wayne, PA: CLSI; 2004.

30. Clinical and Laboratory Standards Institute (CLSI). *User verification of precision and estimation of bias; approved guideline (EP15-A3).* 3rd ed. Wayne, PA: CLSI 2014.

31. Clinical and Laboratory Standards Institute (CLSI). *Method comparison and bias estimation using patient samples; approved guideline (EP02-A2-IR).* Wayne, PA: CLSI 2011.

32. Lapic I, Piva E, Spolaore F, Musso G, Tosato F, Peloso M, et al. Ves-Matic CUBE 200: is modified Westergren method for erythrocyte sedimentation rate a valid alternative to the gold standard? *J Clin Pathol.* 2019;72(10):716–719. https://doi.org/10.1136/jclinpath-2019-205873

33. Lugton RA. The influence of sialic acid on the ESR. *Med Lab Sci.* 1989;46(1):33–38.

34. Sezer S, Yilmaz FM, Kaya O, Uysal S. Evaluation of Ves-Matic Cube 200 for erythrocyte sedimentation rate determination. *J Clin Lab Anal.* 2013;27(5):367–372. https://doi.org/10.1002/jcla.21612

**Original Article** | ESR analyser for ESR detection