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Original Research Article

Comparison of Westergren, Wintrobe, and VES-Matic Automated Methods for Estimation of Erythrocyte Sedimentation Rate in Patients with Liver, Pulmonary, and Renal Disorders

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Abstract:

Background: Erythrocyte sedimentation rate (ESR) is a commonly used, simple, and inexpensive laboratory marker for detecting inflammatory and chronic disease activity. Although the Westergren method is considered the reference method for ESR estimation, conventional methods are time-consuming and require manual handling. Automated ESR methods have been introduced to provide faster reporting and reduce technical errors. Therefore, comparing conventional and automated ESR methods is important in routine laboratory practice.

Aim and Objectives: The present study aimed to compare ESR estimation by Westergren, Wintrobe, and VES-Matic automated methods and to evaluate their utility in patients with liver, pulmonary, and renal disorders.

Materials and Methods: This prospective observational study was conducted in admitted patients with liver, pulmonary, and renal disorders at a tertiary care hospital. A total of 182 patients were included. Patients of both sexes and all age groups with deranged liver function tests, deranged renal function tests, or pulmonary disorders diagnosed clinically and radiologically were enrolled. ESR was estimated in all patients by Westergren, Wintrobe, and VES-Matic automated methods. Data were analyzed using frequencies, percentages, means, standard deviations, and the chi-square test. A p-value <0.05 was considered statistically significant.

Results: Out of 182 patients, 126 were males, and 56 were females, with a male-to-female ratio of 2.25:1. Liver disorders were present in 62 patients (34.1%), lung disorders in 69 patients (37.9%), and renal disorders in 51 patients (28.0%). Overall, abnormal ESR was detected in 147 patients (80.8%) by the Westergren method, 129 patients (70.9%) by the Wintrobe method, and 131 patients (72.0%) by the automated method. The mean ESR was highest by the Westergren method (45.79±27.83 mm/hr.), followed by the automated method (36.97±25.10 mm/hr.), and lowest by the Wintrobe method (29.68±17.70 mm/hr.). The difference between the three methods was statistically significant (p<0.001). Disease-wise, abnormal ESR by the Westergren method was observed in 46 liver disease patients (74.2%), 57 lung disease patients (82.6%), and 44 renal disease patients (86.3%). The Westergren method showed a statistically significant association with disease category (p=0.03), whereas Wintrobe and automated methods did not.

Conclusion: The Westergren method detected the highest number of abnormal ESR values and remains the most sensitive and reliable method for ESR estimation, particularly in patients with high ESR values. The Wintrobe method showed lower ESR values and may underestimate abnormal ESR in some cases. The VES-Matic automated method showed closer agreement with the Westergren method than the Wintrobe method. It may be used as a faster and safer alternative in routine laboratories after proper validation.

Keywords: Erythrocyte Sedimentation Rate; Westergren Method; Wintrobe Method; VES-Matic; Automated ESR; Renal Disorders; Pulmonary Disorders; Liver Disorders.

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Introduction

Cyanide poisoning remains an important forensic Erythrocyte sedimentation rate (ESR) is one of the oldest and most frequently requested hematological investigations used in routine clinical practice. It measures the rate at which anticoagulated erythrocytes settle in a vertical column over a defined period, usually expressed as millimeters per hour. Although ESR is a non-specific marker, it remains clinically useful as an indirect indicator of inflammation, infection, tissue injury, autoimmune

activity, and malignancy [1]. Its value lies not as a standalone diagnostic test but as a simple, inexpensive, and widely available laboratory parameter that can support clinical assessment and monitor disease activity or therapeutic response in selected conditions [2].

Both plasma and cellular factors influence the ESR principle. During inflammation, acute-phase reactants such as fibrinogen, immunoglobulins, and other plasma proteins reduce the negative surface charge (zeta potential) of erythrocytes. This promotes rouleaux formation, allowing red blood cells to sediment more rapidly [3]. Conversely, conditions affecting red cell number, size, or morphology, such as polycythemia, sickle cell disease, marked microcytosis, or spherocytosis, may reduce ESR despite the presence of disease. Technical variables, including tube position, room temperature, vibration, sample age, anticoagulant ratio, and observer error, may also affect ESR results [4].

The Westergren method has traditionally been accepted as the reference method for ESR estimation because of its standardized tube dimensions, reproducibility, and sensitivity, particularly at higher ESR values [5]. The Wintrobe method is another conventional manual technique that requires less column height and permits estimation of packed cell volume from the same tube. Still, it may be less sensitive at markedly elevated ESR levels. Both conventional methods are simple and inexpensive; however, they require manual handling, larger blood volumes, longer reporting times, and a greater risk of pre-analytical and observer-related variation [6].

In recent years, automated ESR analyzers such as VES-Matic systems have been introduced to improve laboratory workflow, reduce biohazard exposure, shorten turnaround time, and minimize manual reading errors. These systems use closed tubes, optical or photometric detection, automated mixing, and mathematical conversion to report ESR values comparable to those of the Westergren method. The International Council for Standardization in Hematology has recommended that modified and alternate ESR methods should be validated against the Westergren reference method before routine clinical use [7]. Therefore, comparing automated and conventional techniques is essential, especially in laboratories managing high sample loads.

ESR is frequently altered in chronic renal, pulmonary, and liver disorders. In renal diseases, elevated ESR may result from anemia, hypoalbuminemia, elevated fibrinogen, chronic inflammation, uremia, and associated infections. In pulmonary disorders such as tuberculosis, pneumonia, chronic obstructive pulmonary disease, pleural effusion, and lung malignancy, ESR may reflect the inflammatory burden and may be useful in assessing disease activity or response to treatment [8]. In liver disorders, ESR may show variable changes depending on the balance among inflammation, altered plasma protein synthesis, hypoalbuminemia, hyperglobulinemia, and reduced hepatic production of acute-phase proteins in advanced liver failure [9].

Despite its non-specific nature, ESR remains widely used in resource-limited and high-volume clinical settings due to its low cost and practical utility. However, differences between manual and automated methods may affect interpretation, especially when ESR is used for monitoring chronic systemic diseases. Therefore, the present study was designed to compare ESR estimation using the Westergren, Wintrobe, and VES-Matic automated methods and to evaluate their utility in renal, pulmonary, and liver disorders.

Materials And Methods

The present prospective observational study was conducted in the Department of Pathology in collaboration with the Departments of Pulmonary Medicine, Surgery, and Medicine at Rux Maniben Deep Chand Gardi Medical College, Ujjain. The study included admitted patients diagnosed with liver, renal, and pulmonary disorders. A total of 182 patients were included during the study period. Detailed clinical history, examination findings, radiological findings, and laboratory investigation details were recorded in a predesigned proforma.

Patients of both sexes and all age groups were included if they had evidence of liver, renal, or pulmonary disease. Liver disorder cases were identified based on deranged liver function tests, including serum glutamic oxaloacetic transaminase, serum glutamic pyruvic transaminase, and alkaline phosphatase. Renal disorder cases were identified based on deranged renal function tests, including blood urea and serum creatinine. Pulmonary disorder cases were identified using clinical findings, chest X-ray, and sputum examination, wherever applicable. Healthy individuals and patients with normal liver function tests, normal renal function tests, normal chest X-ray, and normal sputum examination were excluded from the study. Patients who have other osteopathological conditions likely to influence ESR beyond liver, renal, and pulmonary disorders were also excluded.

For each enrolled patient, venous blood was collected under aseptic precautions. ESR was estimated in all cases using three methods: the Westergren method, the Wintrobe method, and the VES-Matic automated method. The results obtained by the three methods were compared with respect to ESR value, abnormal ESR detection, time required

for reporting, volume of blood required, equipment requirement, and practical utility.

For the Westergren method, 2 ml of venous blood was collected in 0.5 ml of 3.8% sodium citrate solution, maintaining a blood-to-anticoagulant ratio of 4:1. The anticoagulated blood sample was mixed thoroughly and filled into a clean, dry Westergren tube to the zero mark, avoiding air bubbles. The Westergren tube was then placed vertically on the ESR stand and left undisturbed for 1 hour at room temperature. Care was taken to avoid direct sunlight, vibration, and tilting of the tube. At the end of exactly one hour, the height of the clear plasma column above the red cell column was measured in millimeters and reported as ESR (mm/hr).

For the Wintrobe method, anticoagulated venous blood was properly mixed and filled into the Wintrobe tube to the zero mark using a rubber bulb or mechanical device, ensuring no air bubbles were present. The tube was placed vertically in the Wintrobe stand and left undisturbed for one hour. After one hour, the height of the plasma column above the sedimented red cells was recorded in millimeters. The Wintrobe tube used in this method was 110 mm in length with an internal diameter of approximately 3 mm. This method also allows estimation of packed cell volume using the same tube after centrifugation. The Wintrobe method was considered more reliable at lower ESR values, whereas the Westergren method was considered more sensitive at higher ESR values.

For the VES-Matic automated method, specially designed VES-Matic Easy tubes were used. These tubes were prefilled with 0.25 ml of sodium citrate and filled with blood up to the indicated mark. The blood level was maintained between the lower and upper marks. The filled tubes were placed in the VES-Matic Easy analyzer. The analyzer holds the tubes at an angle of approximately 18 degrees, which enhances erythrocyte sedimentation. The system uses infrared optical reading to track the erythrocyte–plasma interface and performs multiple measurements. The linear portion of the sedimentation curve is analyzed by instrument software, and the ESR result is obtained after 20 minutes. This method allows simultaneous processing of 10 samples, requires a smaller sample volume, reduces manual handling, and provides faster reporting compared with conventional manual methods.

Strict precautions were followed during ESR estimation. The correct blood-to-anticoagulant ratio was maintained in all samples. Blood and anticoagulants were mixed thoroughly to avoid clot formation. Tubes were checked for air bubbles before testing. Manual ESR tubes were kept strictly vertical and undisturbed throughout the testing period. The tests were performed at room temperature, preferably between 18°C and 25°C, as higher room temperature or tube tilting can increase ESR values. Samples were processed within the permissible time after collection to reduce pre-analytical error.

The data collected were entered into a master chart and analyzed statistically. Quantitative variables were expressed as mean and standard deviation. Qualitative variables were expressed as frequency and percentage. Abnormal ESR values detected by Westergren, Wintrobe, and automated methods were compared across age groups, genders, and disease categories. The chi-square test was used to compare categorical variables. Mean ESR values obtained by the different methods were compared statistically. A p-value of less than 0.05 was considered statistically significant.

Results

The present study included 182 patients with liver, lung, and renal disorders. In all patients, erythrocyte sedimentation rate (ESR) was estimated by three methods: the Westergren method, the Wintrobe method, and the VES-Matic automated method. The patients' ages ranged from 10 to 84 years. Out of 182 patients, 126 were males, and 56 were females, giving a male-to-female ratio of 2.25:1. Overall, abnormal ESR was detected in 147 patients (80.8%) by the Westergren method, 129 patients (70.9%) by the Wintrobe method, and 131 patients (72.0%) by the automated method.

Table 1: Baseline characteristics of the study population

Baseline variable	Frequency	Percentage
Total patients	**182**	**100.0%**
Age range	10–84 years	—
Male	126	69.2%
Female	56	30.8%
Male: Female ratio	2.25:1	—
Liver disease	62	34.1%
Lung disease	69	37.9%
Renal disease	51	28.0%

Table 2: Age-wise distribution of abnormal ESR values by different methods

Age group	Total cases	Westergren abnormal n (%)	Wintrobe abnormal n (%)	Automated abnormal n (%)
≤20 years	14	10 (71.4%)	6 (42.9%)	7 (50.0%)
21–30 years	30	25 (83.3%)	22 (73.3%)	22 (73.3%)
31–40 years	37	31 (83.8%)	26 (70.3%)	27 (73.0%)
41–50 years	29	22 (75.9%)	19 (65.5%)	19 (65.5%)
51–60 years	42	36 (85.7%)	35 (83.3%)	34 (81.0%)
61–70 years	22	17 (77.3%)	16 (72.7%)	16 (72.7%)
>70 years	8	6 (75.0%)	5 (62.5%)	6 (75.0%)
Total	**182**	**147 (80.8%)**	**129 (70.9%)**	**131 (72.0%)**
p value	—	**0.859**	**0.158**	**0.456**

Table 3: Gender-wise distribution of abnormal ESR values by different methods

ESR method	Female abnormal n/N (%)	Male abnormal n/N (%)	p value
Westergren method	49/56 (87.5%)	98/126 (77.8%)	0.125
Wintrobe method	45/56 (80.4%)	84/126 (66.7%)	0.061
Automated method	49/56 (87.5%)	82/126 (65.1%)	0.002

Table 4: Comparison of mean ESR values by different methods

ESR method	Mean ESR	N	Standard deviation
Westergren method	45.79	182	27.833
Wintrobe method	29.68	182	17.695
Automated method	36.97	182	25.101

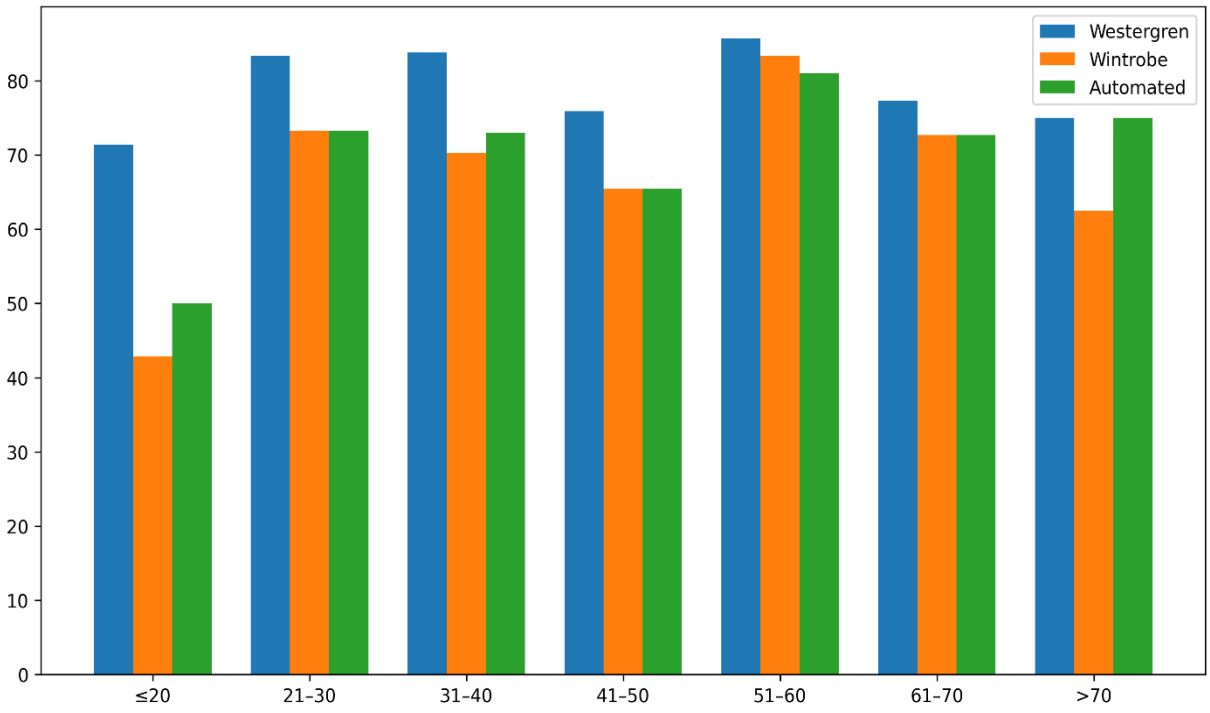

Figure 1: shows the age-wise distribution of abnormal ESR values measured by Westergren, Wintrobe, and VES-Matic automated methods. The Westergren method detected a higher proportion of abnormal ESR values across most age groups compared with the Wintrobe and automated methods. In patients aged ≤20 years, abnormal ESR was observed in 71.4% by the Westergren method, 42.9% by the Wintrobe method, and 50.0% by the automated method. In the 21–30-year age group, abnormal ESR was detected in 83.3% by Westergren, 73.3% by Wintrobe, and 73.3% by automated methods. In the 31–40-year age group, abnormal ESR was observed in 83.8%, 70.3%, and 73.0% by the Westergren, Wintrobe, and automated methods, respectively. The highest abnormal ESR detection rate by Westergren was observed in the 51–60-year age group (85.7%). However, the association between age and abnormal ESR was not statistically significant using the Westergren method (p=0.859), the Wintrobe method (p=0.158), or the automated method (p=0.456).

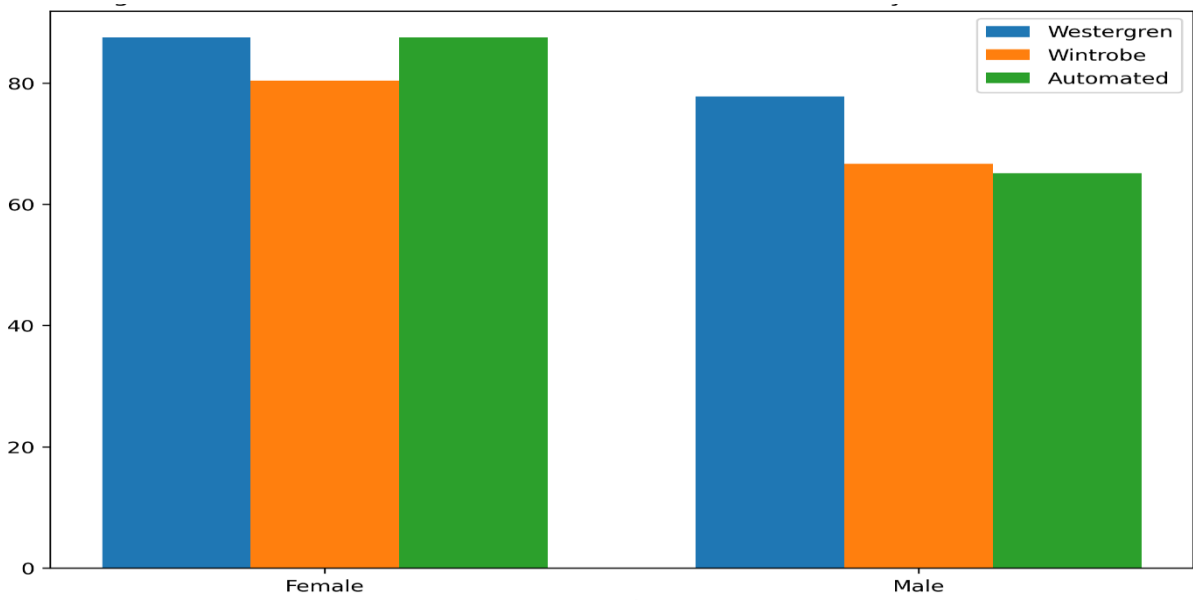

Figure 2: demonstrates the gender-wise distribution of abnormal ESR values by the three ESR estimation methods. Female patients showed a higher proportion of abnormal ESR values than male patients by all methods. By the Westergren method, abnormal ESR was observed in 87.5% of females and 77.8% of males. By the Wintrobe method, abnormal ESR was detected in 80.4% of females and 66.7% of males. Similarly, by the automated method, abnormal ESR was found in 87.5% of females and 65.1% of males. The difference between males and females was statistically significant only for the automated method (p=0.002), while the association was not statistically significant for the Westergren method (p=0.125) and Wintrobe method (p=0.061).

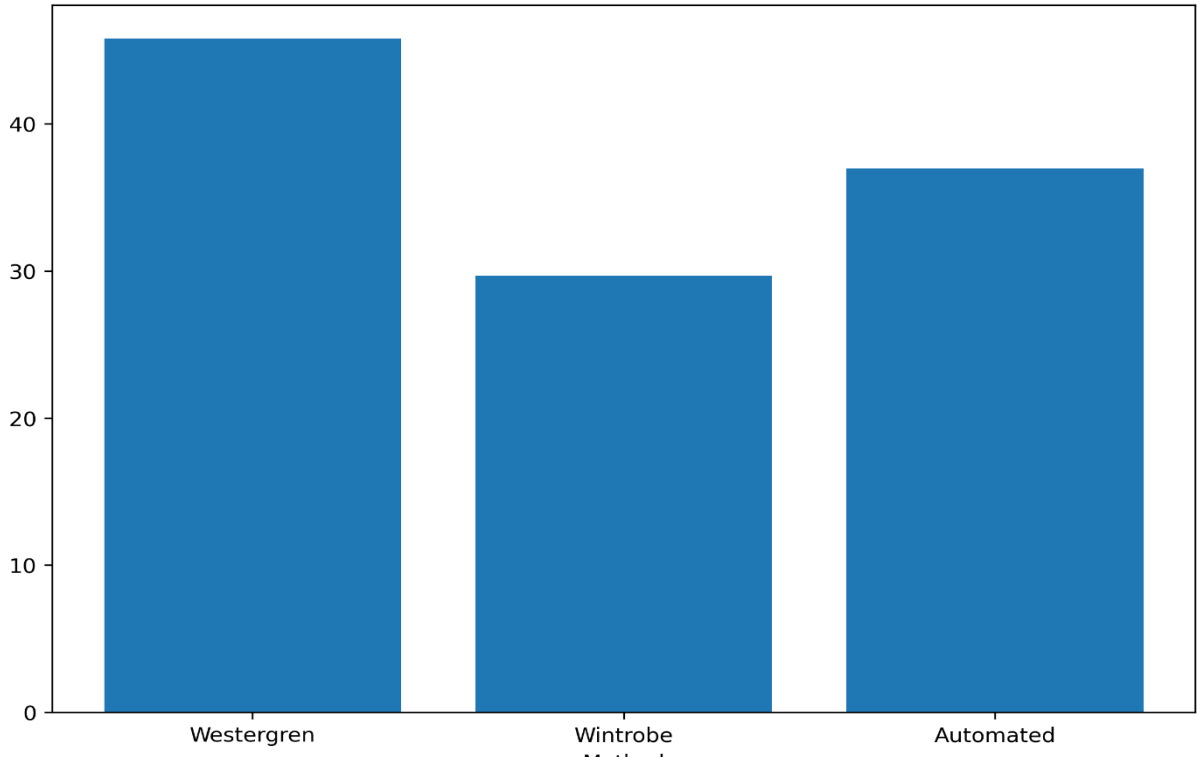

Figure 3: compares the mean ESR values obtained by Westergren, Wintrobe, and VES-Matic automated methods. The highest mean ESR value was recorded by the Westergren method (45.79±27.83 mm/hr), followed by the automated method (36.97±25.10 mm/hr). The lowest mean ESR value was recorded by the Wintrobe method (29.68±17.70 mm/hr). Pairwise comparisons showed statistically significant differences between the Westergren and Wintrobe methods, the Westergren and automated methods, and the Wintrobe and automated methods ($p<0.001$ for all comparisons). These findings indicate that although all three methods are used for ESR estimation, they produce different mean values, with Westergren giving the highest readings.

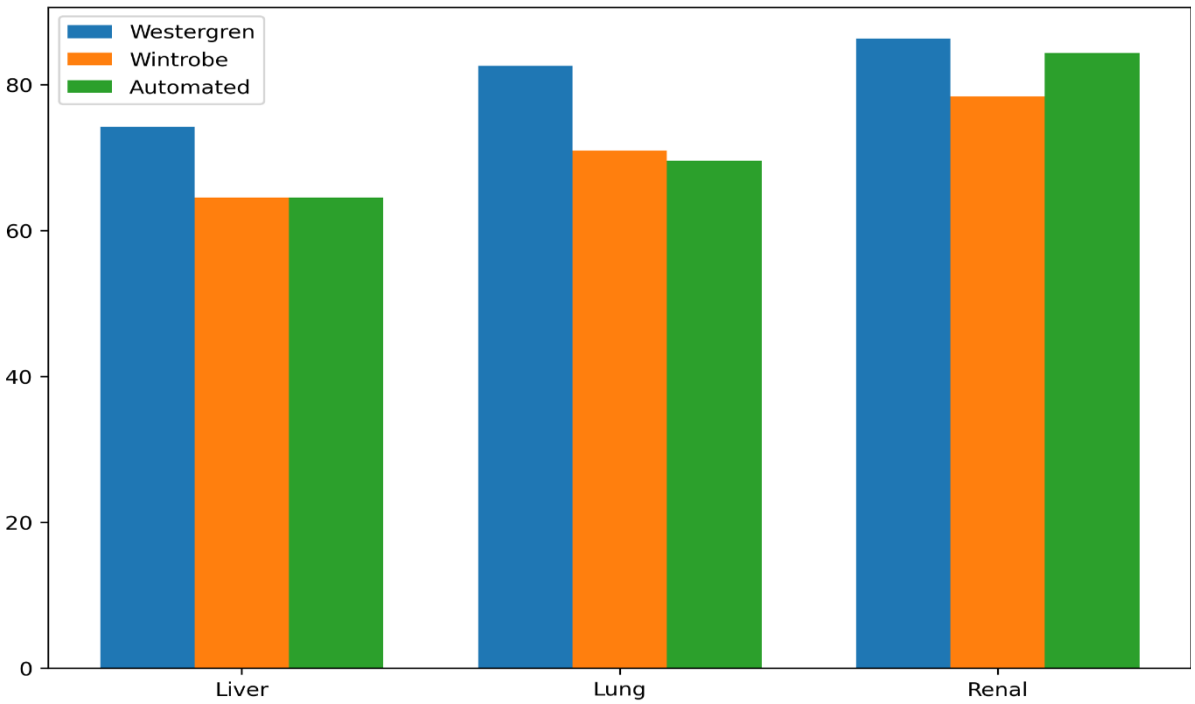

Figure 4: shows the disease-wise distribution of abnormal ESR values among patients with liver, lung, and renal disorders. By the Westergren method, abnormal ESR was detected in 74.2% of patients with liver disease, 82.6% of patients with lung disease, and 86.3% of patients with renal disease. By the Wintrobe method, abnormal ESR was observed in 64.5% of patients with liver disease, 71.0% of patients with lung disease, and 78.4% of patients with renal disease. Using the automated method, abnormal ESR was detected in 64.5% of patients with liver disease, 69.6% of patients with lung disease, and 84.3% of patients with renal disease. Renal disorders showed the highest proportion of abnormal ESR values, particularly by Westergren and automated methods. The association between disease category and abnormal ESR was statistically significant for the Westergren method (p=0.03), but not for the Wintrobe method (p=0.38) or the automated method (p=0.32).

Discussion

The present study was conducted to compare the results of erythrocyte sedimentation rate (ESR) estimation by Westergren, Wintrobe, and VES-Matic automated methods in patients with liver, pulmonary, and renal disorders. ESR is one of the most widely used laboratory investigations for assessing inflammatory activity. Still, it is a non-specific marker and cannot be used alone to diagnose a particular disease. Its value lies mainly in supporting clinical diagnosis, assessing disease activity, and monitoring treatment response in selected inflammatory, infective, autoimmune, renal, pulmonary, hepatic, and malignant conditions [1].

In the present study, 182 patients were included. Among them, 62 patients had liver disorders, 69 patients had pulmonary disorders, and 51 patients had renal disorders. The maximum number of patients belonged to the 51–60 years age group, followed by the 31–40 years age group. The fewest cases were observed among patients older than 70 years. ESR abnormalities were observed across all age groups, although no statistically significant association was found between age group and abnormal ESR values by Westergren, Wintrobe, or automated methods. ESR is known to increase with age, but in disease-based hospital populations, inflammatory burden, anemia, plasma protein changes, renal dysfunction, infection, and tissue injury may have a greater effect on ESR than age alone [2].

In the present study, males comprised 126 cases and females 56, with a male-to-female ratio of 2.25:1. Female patients had a higher proportion of abnormal ESR values than male patients across all three methods. By the Westergren method, abnormal ESR was observed in 87.5% of females and 77.8% of males. By the Wintrobe method, abnormal ESR was detected in 80.4% of females and 66.7% of males. By the automated method, abnormal ESR was detected in 87.5% of females and 65.1% of males. The gender-wise difference was statistically significant only by the automated method. Similar observations have been reported in the literature, in which ESR values were found to be influenced by sex, hematocrit, anemia, plasma proteins, and physiological factors [5]. Lower hematocrit levels, nutritional anemia, menstrual blood loss, and other physiological factors may partly explain the higher ESR among females in the present study.

The Westergren method detected the maximum number of abnormal ESR values in the present study. Abnormal ESR was found in 147 patients (80.8%) by the Westergren method, 129 patients (70.9%) by the Wintrobe method, and 131 patients (72.0%) by the VES-Matic automated method. This finding supports the Westergren method's established role as the reference method for ESR estimation. The International Council for Standardization in Hematology has recommended the Westergren method as the reference method, and that modified or alternative ESR methods be validated against the Westergren method before routine clinical application [7].

The mean ESR value was highest by the Westergren method (45.79±27.83 mm/hr.), followed by the VES-Matic automated method (36.97±25.10 mm/hr.), while the lowest mean ESR was observed by the Wintrobe method (29.68±17.70 mm/hr.). The differences between Westergren and Wintrobe, Westergren and automated, and Wintrobe and automated methods were statistically significant. These findings indicate that although all three methods measure ESR, their values are not identical. The lower values obtained by the Wintrobe method may be due to the shorter tube length, which limits sedimentation at higher ESR values and may underestimate markedly raised ESR. Therefore, the Wintrobe method may occasionally give misleadingly low or normal values in patients with clinically active diseases.

Our findings are comparable with those of Asif et al., who validated automated ESR methods against the conventional Westergren method and reported a strong positive correlation between Westergren and VES-Matic methods [11]. In their study, mean ESR values by Westergren were slightly higher than those obtained by the automated method. Similarly, Cerutti et al. compared VES-Matic Cube 80 with the Westergren method and reported that the automated system provided fast, safe ESR determination with good correlation with the reference method [12]. In the present study, the VES-Matic automated method also yielded ESR values closer to those of the Westergren method than the Wintrobe method, supporting its practical utility in routine laboratory settings.

The automated method has several practical advantages over conventional manual methods. It reduces manual handling of blood, decreases biohazard exposure, shortens turnaround time, requires smaller sample volume, and reduces observer-dependent reading errors. These benefits are important in high-volume laboratories and tertiary care hospitals. However, automated methods may use different principles such as optical detection, photometric reading, mathematical conversion, or shortened sedimentation time. Therefore, their results should not be considered automatically interchangeable with Westergren values unless proper validation is performed [13]. The present study supports the use of the VES-Matic method as a practical alternative, but the Westergren method remains the preferred reference method.

Disease-wise analysis showed that renal disorders had the highest proportion of abnormal ESR values. By the Westergren method, abnormal ESR was observed in 44 of 51 patients with renal disease (86.3%). By the Wintrobe method, abnormal ESR was found in 40 patients (78.4%), and by the automated method, in 43 patients (84.3%). ESR elevation in renal disease may be due to chronic inflammation, anemia, hypoalbuminemia, altered plasma protein levels, increased fibrinogen, and a uremic milieu. Bathon et al. reported that ESR was elevated in a high proportion of patients with end-stage renal failure and observed that dialysis did not significantly change ESR values [14]. Also, Maili et al. evaluated ESR in patients with stable chronic hemodialysis and discussed its determinants and interpretation in this population [15]. The findings of the present study are consistent with these observations, showing frequent elevations in ESR among patients with renal disorders.

Among pulmonary disorders, abnormal ESR was detected in 57 of 69 patients (82.6%) by the Westergren method, 49 of 69 patients (71.0%) by the Wintrobe method, and 48 of 69 patients (69.6%) by the automated method. Pulmonary diseases such as tuberculosis, pneumonia, chronic obstructive pulmonary disease, pleural effusion, and lung malignancy are commonly associated with systemic inflammation and increased acute-phase reactants, leading to elevated ESR. Al-Marri and Kirkpatrick reported that ESR remained useful in childhood tuberculosis and showed a significant elevation in tuberculosis cases [16]. ESR has also been used as a supportive marker for assessing disease activity and response to antitubercular therapy. In the present study, elevated ESR in pulmonary disorders may be related to chronic infection, inflammatory activity, and tissue damage.

In liver disorders, abnormal ESR was observed in 46 of 62 patients (74.2%) by the Westergren method and in 40 patients (64.5%) each by the Wintrobe and automated methods. ESR changes in liver disease may be variable because the liver plays a central role in the synthesis of plasma proteins, including albumin and several acute-phase reactants. In inflammatory liver disorders, viral hepatitis, alcoholic liver disease, and metabolic liver disease, ESR may rise because of systemic inflammation and altered plasma protein balance. However, in advanced hepatic failure, reduced hepatic synthesis of acute-phase proteins may limit the elevation of ESR despite severe disease. Das et al. compared hematological parameters in non-alcoholic fatty liver disease and alcoholic liver disease and reported

significant hematological changes in alcoholic liver disease [8]. In the present study, most patients with liver disorders showed elevated ESR, suggesting active inflammation or systemic involvement.

The disease-wise association was statistically significant for the Westergren method, whereas no significant association was observed for the Wintrobe and automated methods. This finding suggests that the Westergren method was more sensitive in detecting abnormal ESR variation across liver, pulmonary, and renal disorders. The Wintrobe method showed lower rates of abnormal detection and lower mean ESR values, suggesting it may underestimate ESR, particularly in cases with high inflammatory burden. The automated method performed better than Wintrobe and showed closer agreement with Westergren, although it did not show significant disease-wise association in the present study.

The clinical relevance of ESR must be interpreted carefully. ESR is affected not only by inflammatory disease but also by anemia, age, sex, red blood cell morphology, plasma fibrinogen, immunoglobulin levels, albumin concentration, temperature, tube position, anticoagulant ratio, and technical handling. Therefore, ESR should not be used as an isolated diagnostic test. It should be interpreted along with clinical findings, liver function tests, renal function tests, complete blood count, sputum examination, radiology, and other disease-specific investigations. Brigden emphasized that ESR remains useful in selected clinical settings but has limited specificity and should be used rationally [1].

The present study has certain limitations. It was conducted in a single tertiary care Centre and included only patients with liver, pulmonary, and renal disorders. The sample size within each disease subgroup was limited. The study compared ESR methods primarily by abnormal ESR detection, mean ESR values, and disease-wise distribution, but detailed agreement analyses, such as Bland–Altman limits of agreement and correlation coefficients, were not fully explored in the final interpretation. Other factors influencing ESR, such as hemoglobin level, fibrinogen, albumin, globulin, and C-reactive protein, were not analyzed in detail. Despite these limitations, the study provides useful practical information regarding the comparative performance of conventional and automated ESR methods in routine clinical samples.

Overall, the present study showed that the Westergren method detected the highest number of abnormal ESR values and produced the highest mean ESR values. The Wintrobe method showed lower ESR values and may underestimate ESR in some clinically active cases. The VES-Matic automated method yielded values closer to those of the Westergren method and offered advantages in speed, safety, reduced manual handling, and improved workflow. Therefore, the Westergren method remains the reference and most sensitive method for ESR estimation. In contrast, the VES-Matic automated method may be considered a useful alternative in routine laboratories after proper validation.

Conclusion

ESR remains a useful but non-specific inflammatory marker that supports clinicians in the diagnosis and follow-up of various disease conditions, including malignancy, hepatic, pulmonary, and renal diseases. In the present study, ESR values increased with age and were comparatively higher in female patients. Among the conventional methods, the Westergren method was found to be simple, inexpensive, more sensitive, and more reliable, especially in cases with high ESR values. In contrast, the Wintrobe method showed normal or misleading results in some clinically ill patients. The Westergren method also showed a significant association with disease conditions, supporting its superiority for ESR estimation. However, because the Westergren method is time-consuming and requires a relatively larger blood volume, newer approaches such as micro-ESR, centrifugation-based methods, and automated ESR analyzers may be useful alternatives, particularly in critically ill patients, infants, neonates, and patients requiring repeated sampling.

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