Shiraz E-Med J. ; In Press(In Press): e153673 https://doi.org/10.5812/semj-153673

Published Online: 2024 December 11 **Research Article**

Information Requirements of Clinical Decision Support Systems for the Diagnosis and Prediction of Preeclampsia

Nazanin Khayatan [1], Nasim Aslani [1,*], Ali Garavand [1], Nasrin Galehdar [2], Vadad Khayatan [3]

[1] Department of Health Information Technology, School of Allied Medical Sciences, Lorestan University of Medical Sciences, Khorramabad, Iran
[2] School of Allied Medical Sciences, Lorestan University of Medical Sciences, Khorramabad, Iran
[3] Mahdieh Hospital, Tehran, Iran

[*] ***Corresponding Author:*** Department of Health Information Technology, School of Allied Medical Sciences, Lorestan University of Medical Sciences, Khorramabad, Iran. Email: aslaninasim@yahoo.com

Received: 18 August, 2024; **Revised:** 13 November, 2024; **Accepted:** 17 November, 2024

Abstract

Background: Clinical decision support systems (CDSS) are valuable tools for diagnosing and predicting diseases. However, their effectiveness hinges on the quality of the information provided.

Objectives: This study aimed to identify the information requirements for a CDSS designed to diagnose and predict preeclampsia.

Methods: This applied study was conducted in 2024. A literature review was performed to identify relevant studies. Based on the findings, a questionnaire with a five-point Likert scale was developed and validated through the input of 22 experts in related fields. Data were analyzed using SPSS version 22, and the findings are presented in the text and tables.

Results: Among 143 items identified, 115 were deemed essential for a CDSS to diagnose and predict preeclampsia. The information requirements were classified into eight main categories: Demographic information, medical history, laboratory data, pregnancy-related data, complications in other organs, medical examinations, warning signs, paraclinical data, and lifestyle.

Conclusions: The findings of this study provide critical insights for developers of CDSS tailored to preeclampsia diagnosis and prediction. By addressing these information needs, such systems can significantly enhance the capabilities of women's health professionals, advancing timely diagnosis and prevention of preeclampsia.

Keywords: Preeclampsia, Decision Support Systems, Information Requirements

1. Background

The complexity of women's health extends beyond medical and surgical knowledge and clinical obstetric advancements. During the sensitive period of pregnancy, women face various complications and disorders. Among the most significant and controversial unresolved issues in obstetrics are hypertensive disorders, particularly preeclampsia (1-3).

Preeclampsia is often characterized by hypertension accompanied by proteinuria; however, this disorder encompasses more than elevated blood pressure and protein in the urine. Proteinuria remains one of the most critical diagnostic criteria for this condition. Preeclampsia is a pregnancy-specific syndrome that can potentially affect nearly every organ system. It is a multisystem disorder occurring in 3 to 8 percent of pregnancies in the United States and 1.5 to 16.7 percent globally. Each year, it leads to approximately 60 000 maternal deaths and over 500 000 infant mortalities worldwide (4-6).

Women with preeclampsia are at risk of various complications, including seizures (eclampsia), cardiovascular disease, and acute kidney injury. Additionally, their offspring are at higher risk of adverse outcomes such as premature birth, fetal growth restriction, and intrauterine fetal demise. The only therapeutic interventions currently available for affected mothers are blood pressure control and early delivery (7-9). These severe consequences and the lack of

effective treatment methods highlight the critical need for preventive measures.

In recent years, healthcare providers have increasingly leveraged innovative technologies like health information systems to predict and manage diseases. Clinical decision support systems (CDSS) are among the most essential tools within health information systems (10). Clinical decision support systems software is designed to directly assist in clinical decision-making. Its functionalities are wide-ranging, encompassing diagnosis, alert systems, disease management, medication management, and more. However, the effectiveness of CDSS in managing conditions like preeclampsia depends on the quality and comprehensiveness of the data it processes (11-14).

A significant advantage of rule-based CDSS is their ability to enhance adherence to medical guidelines and protocols. The robust knowledge base of these systems enables them to provide alerts, reminders, treatment plans, and specific diagnostic and therapeutic recommendations by integrating and cohesively assessing patient information. Clinical decision support systems offer numerous key benefits, including improved patient safety, reduced medical errors, cost savings, enhanced collaboration among healthcare teams, and, most importantly, support for the timely diagnosis of diseases (14-16).

Research demonstrates that information technology serves as a powerful tool in predicting diseases and addressing maternal and women's health disorders. For instance, Liu et al. developed a decision support system that analyzed clinical data from prenatal and early pregnancy screenings to predict preeclampsia in pregnant women. The system automatically identified a set of predictive features, achieving high performance in assessing preeclampsia risk using early pregnancy data (17).

Similarly, Jhee et al. conducted a study to create a predictive model for late-onset preeclampsia using computer-based methods. Their system incorporated information such as age, blood pressure, BMI, gestational age, history of hypertension, previous preeclampsia, and diabetes. Laboratory data, including blood nitrogen and urea levels, were also utilized. The resulting CDSS demonstrated improved prediction accuracy compared to traditional statistical methods (18).

In another study, Wang et al. developed a CDSS to evaluate the risk of cardiac diseases in women with preeclampsia. This study exemplifies the effectiveness of CDSS tailored to women's health issues, highlighting the value of incorporating essential information requirements for predicting and managing diseases (19).

2. Objectives

Given the critical role of decision support systems in predicting and diagnosing diseases in a timely manner, as well as the importance of a comprehensive and accurate knowledge base for their optimal functionality, the present study aimed to identify the essential information requirements for a decision support system based on established medical guidelines.

3. Methods

This applied study was conducted in 2024 and comprised two main steps. The first step involved identifying requirements through content analysis of related studies and the Delphi technique. In the second step, information needs were determined based on the results from the first step.

3.1. First Step

A review was conducted to determine the information requirements. Searches were performed on PubMed, Web of Science, Scopus, and Cochrane using keywords such as “dataset,” “minimum dataset,” “CDSS,” and “preeclampsia” to locate relevant articles without time restrictions. Additionally, related websites, such as those of the World Health Organization, and guidelines from reputable global women's surgery associations were reviewed to identify other relevant texts, including reports, standards, and guidelines. Articles specifically related to CDSS and preeclampsia, as well as studies addressing preeclampsia datasets, were included. Other study types were excluded, except for review articles, letters, and short communications. Data extraction was independently carried out by two authors (N.Kh and A.G) using a structured data extraction form. Content analysis was used for data analysis, and the results were presented in both text and tables.

3.2. Second Step

Based on the results of the first step, a questionnaire was developed to identify essential information requirements. The study population consisted of relevant experts, including gynecological surgeons (5 individuals), obstetricians, midwifery specialists (7

individuals), and health information management (HIM) professionals (10 individuals). Purposeful sampling was employed, and experts with at least three years of professional experience were selected.

The experts were asked to evaluate each data item using a Likert Scale. Additionally, they were invited to suggest important information items by adding them at the end of each section of the questionnaire. Data items with a confirmation rate exceeding 75% were approved, while those scoring below 50% were removed. Information elements scoring between 50% and 75% proceeded to the next round of the Delphi method.

Data analysis was conducted using descriptive statistical methods, such as percentages and frequencies, with the assistance of SPSS software (version 22). The analyzed data were presented in tables for clarity.

4. Results

This study initially identified data elements through a questionnaire developed by reviewing previous studies and medical guidelines. Subsequently, essential information elements were determined based on the opinions of the research participants. The demographic characteristics of the participants are shown in Table 1.

Table 1. Participants' Demographic Information [a]

Parameter and Categories	Values
Age, y	
30 - 35	7 (31.81)
35 - 40	7 (31.81)
> 40	8 (36.38)
Field of study	
HIM	10 (45.45)
Gynecological surgery	7 (31.81)
Midwifery specialist	5 (22.74)
Grade level	
BSc.	4 (18.18)
MSc.	1 (4.54)
PhD	10 (45.45)
OB-GYN specialist	7 (31.81)
Work experience, y	
< 5	3 (13.63)
5 - 10	9 (40.90)
> 10	10 (45.47)

Abbreviation: HIM, health information management.

[a] Values are expressed as No. (%).

According to Table 1, most participants were aged 40 or older and had more than 10 years of professional experience.

Table 2 presents the results of the first round of expert opinion polling conducted using the Delphi technique. It includes essential data elements for CDSS for preeclampsia prevention.

Table 2. Results of Identifying Information Requirements for Clinical Decision Support Systems in Preeclampsia Prevention (First Round of Delphi) [a]

Categories and Information Requirements	Frequency			Result
	Mean	SD	Percentage	
Mother's Personal Information				
1. First name	3.59	1.07	71	*
2. Last name	3.64	1.18	72.8	*
3. Father's name	3.5	1.72	70	*
4. Spouse's name	3.45	1.33	69	*
5. Spouse's last name	3.45	1.31	69	*
6. Date of birth	4.18	0.92	86.3	√
7. Place of birth	3.77	1.04	75.4	√
8. Residence	3.95	1.21	79	√
9. National ID	3.73	1.03	74.6	*
10. Mother's age	4.91	0.18	98.2	√
11. Spouse's age	4.14	1.01	82.8	√
12. Spouse's occupation	4.27	0.86	85.4	√
13. Ethnicity	3.77	1.17	75.4	√
14. Employment status	4.32	1.02	86.4	√
15. Education level	4	1.03	80	√
16. Income level	3.91	0.88	78.2	√
17. Nationality	4.09	0.26	81.8	√
18. Religion	3.14	1.11	62.8	*
19. Mother's contact number	3.91	1.04	78.2	√
20. Spouse's contact number	3.68	1.21	73.6	*
21. Email	2.45	1.34	49	×
22. File number	3.45	0.93	69	*
Medical history				
23. History of kidney disease	4.36	1.04	87.2	√
24. History of autoimmune diseases	4.45	067	89	√
25. History of inflammatory bowel disease	4.36	0.62	87.2	√
26. History of heart disease	4.5	0.53	90	√
27. History of vascular disease	4.55	0.49	91	√
28. History of thyroid disease	4.36	0.43	87.2	√
29. History of uncontrolled hyperthyroidism	3.73	1.08	74.6	*
30. History of seizure disorder	3.68	1.00	73.6	*
31. History of chronic hypertension	4.86	0.37	97.2	√
32. History of anemia	3.95	1.03	79	√
33. History of urinary tract infection	3.59	1.19	71.8	*
34. History of type 1 diabetes	4.36	0.82	87.2	√
35. History of type 2 diabetes	4.45	1.15	89	√
36. History of obesity	4.82	0.45	96.4	√
37. History of visual impairments	3.91	1.14	78.2	√
38. History of mental disorders	3.27	1.26	65.4	*
39. History of post-traumatic stress disorder	3.23	1.03	64.6	*
40. History of rheumatism	4	0.56	80	√
41. History of liver disease	4.05	1.07	81	√
42. History of ovarian cyst	3.82	1.26	76.4	√
43. History of sexually transmitted infections	3.5	1.55	70	*
44. History of stroke	3.55	1.14	71	*
45. History of endometriosis	3.73	0.69	74.6	*
46. History of miscarriage	4.64	0.32	92.8	√
47. History of preeclampsia in previous pregnancies	4.77	0.23	95.4	√
48. History of multiple pregnancies	4.82	0.13	96.4	√
Laboratory data				

Categories and Information Requirements	Frequency			Result
	Mean	SD	Percentage	
Mother's Personal Information				
49. Uric acid	4.68	0.18	93.6	√
50. Creatinine	4.64	0.38	92.8	√
51. Urinary protein	4.82	0.13	96.4	√
52. Blood urea nitrogen	4.45	0.57	89	√
53. 24-hour urine collection	4.55	0.23	91	√
54. Triglycerides	3.64	1.02	72.8	*
55. Total cholesterol	3.73	1.05	74.6	*
56. Lipoprotein cholesterol	3.64	1.08	72.8	*
57. Serum potassium level	3.64	0.98	72.8	*
58. Serum magnesium level	3.59	1.43	71.8	*
59. Serum calcium level	3.14	1.98	62.8	*
60. Serum led level	2.95	2.02	59	*
61. Aspartate aminotransferase	4.55	0.48	91	√
62. Alanine aminotransferase	4.55	0.68	91	√
63. Kidney function test	4.59	0.37	91.8	√
64. Hemoglobin	3.95	1.01	79	√
65. Prothrombin time	3.95	1.01	79	√
66. Partial thromboplastin time	3.91	1.19	78.2	√
67. International normalized ratio	3.86	1.24	77.2	√
68. Sex hormone-binding globulin assessment	3.05	2.01	61	*
69. Antibody test	3.41	1.45	68.2	*
70. Pap smear	3.23	2.02	64.6	*
Pregnancy-related data				
71. Mother's age at first pregnancy	4.91	0.32	98.2	√
72. Number of children	4.59	0.27	91.8	√
73. First pregnancy or others	4.91	0.24	98.2	√
74. Multiple gestations	4.91	0.18	98.2	√
75. Preeclampsia in the first pregnancy	4.77	0.48	95.4	√
76. History of in vitro fertilization	4.86	0.17	97.2	√
77. Assisted reproductive technology usage	4.82	0.23	96.4	√
78. Previous childbirth method/last cesarean section	4.5	0.55	90	√
79. Uterine fibroids	4.14	1.01	82.8	√
80. Adenomyosis	4.09	1.00	81.8	√
81. Uterine abnormalities	4.18	0.89	83.6	√
82. Long interval since previous pregnancies	4.36	0.28	87.2	√
83. Previous pregnancy with hypertension	4.86	0.18	97.2	√
84. Type of contraceptive method	4.05	0.23	81	√
85. Hydrops fetalis	3.68	1.25	73.6	*
86. Hyperemesis gravidarum	4.09	1.13	81.8	√
87. Upper abdominal or epigastric pain	4.59	0.67	91.8	√
88. Vaginal bleeding	4.23	0.74	84.6	√
89. Bleeding with abdominal pain	4.41	0.55	88.2	√
90. History of fetus miscarriage	4.55	0.84	91	√
91. History of miscarriage after ten weeks	4.77	0.18	95.4	√
92. History of intrauterine fetal death	4.73	0.47	94.6	√
93. Molar pregnancy	4.41	0.61	88.2	√
94. Ectopic pregnancy	4.18	0.84	83.6	√
95. History of infertility	4.45	0.47	89	√
96. Polycystic ovary syndrome	4.27	0.55	85.4	√
97. Maternal complications in first-degree relatives (mother/sister)	4.5	0.62	90	√
98. Fetal growth restriction	4.64	1.01	92.8	√
99. Oligohydramnios	4.36	0.59	87.2	√
100. Uterine fibroids	4.68	0.89	93.6	√
101. Time of blood pressure detection	4.45	1.03	89	√
102. Antiphospholipid syndrome	4.27	1.01	85.4	√
Complications of preeclampsia in other organs				
103. Thrombocytopenia	4.09	1.03	81.8	√
104. Hemolysis	3.41	1.48	68.2	*
105. Neurological disorders	3.23	2.00	64.6	*
106. Pulmonary edema	3.23	1.37	64.6	*
107. Elevated serum amylase	3.91	1.05	78.2	√
Medical examinations				
108. Weight	4.55	0.41	91	√
109. Height	3.55	1.05	71	*
110. BMI	4.59	0.62	91.8	√
111. Abdominal examination	3.73	1.27	74.6	*
112. Pelvic examination	3.64	1.24	72.8	*
113. Skin examination	3.23	2.00	64.6	*
114. Waist circumference measurement	3.41	1.61	68.2	*
115. Hip circumference measurement	3.23	2.05	66.4	*
116. Arm circumference measurement	3	1.96	60	*
117. Head circumference measurement	2.86	2.05	57.2	*
Warning signs				
118. Severe headaches	4.82	0.18	96.4	√
119. Difficulty breathing	4.73	0.23	94.6	√
120. Nausea or vomiting	4.73	0.27	94.6	√
121. Problems urinating	4.73	0.23	94.6	√
122. Infrequent urination	4.77	0.23	95.4	√
123. Abdominal pain (especially in the upper right side)	4.73	0.44	94.6	√
124. Blurred vision, double vision, or vision loss	4.73	0.27	94.6%	√
125. Swelling of the hands, face, or ankles	4.86	0.73	97.2	√
126. Seizures	4.82	0.28	96.4	√
127. Severe confusion or disorientation	4.77	1.11	95.4	√
128. Loss of consciousness	4.82	0.23	96.4	√
Paraclinical data				
129. Mammography	2.55	2.16	51	*
130. Sonography	2.91	2.05	58.2	*
131. Colonoscopy	2.64	2.00	52.8	*
132. CT scan	2.64	2.00	52.8	*
133. Radiography	2.82	2.03	56.4	*
Lifestyle				
134. Income level	3.91	1.04	78.2	√
135. Socio-economic status	3.91	1.07	78.2	√
136. History of smoking	4.18	0.99	83.6	√
137. History of tobacco use	4.09	0.87	81.8	√
138. Physical activity	3.95	1.03	79	√
139. Dietary habits	4	1.06	80	√
140. Mobile phone usage (per day)	3.18	1.36	63.3	*
141. Television viewing (per day)	2.86	1.51	57.2	*
142. Hours spent on daily activities	3.18	1.36	63.6	*
143. Number of hours of sleep per night	3.59	1.27	71.8	*

[a] Items with an agreement rate exceeding 75% are marked with √. Data elements scoring between 50% and 75%, are marked with *, and proceeded to the second round. Items scoring below 50%, are marked with ×, and were excluded.

In the first round of the Delphi process, experts deemed the email data element non-essential and excluded it from the vital dataset. Conversely, elements such as viral hepatitis, HIV, and certain laboratory data, including serum sodium levels, which experts suggested in the initial round, were included in the second-round questionnaire.

In the second round, 27 of the 48 data items were removed, including religion, spouse's contact number, history of urinary tract infections, history of post-traumatic stress disorder, sexually transmitted diseases, serum calcium level, serum lead level, testosterone evaluation, sex hormone-binding globulin, antibody tests, Pap smear, hydrops fetalis, hemolysis, pulmonary

circumference, mammography, sonography, colonoscopy, CT scan, radiography, daily mobile phone usage, hours spent watching television, and hours of sleep per night.

Ultimately, 93 items were approved in the first round and 22 in the second round, culminating in 115 data items categorized into nine main groups.

5. Discussion

Clinical Decision Support Systems are pivotal in healthcare, particularly in preventing disorders like preeclampsia, where CDSS can significantly contribute to early detection and intervention. Achieving optimal patient health outcomes through these technologies hinges on identifying and incorporating essential information requirements. Based on the findings, a comprehensive database for a CDSS designed to prevent preeclampsia should include diverse data categories such as maternal identity, medical history, laboratory findings, pregnancy-specific data, preeclampsia-related complications in other organs, medical examinations, warning signs, paraclinical data, and lifestyle information.

5.1. Demographic Data

Personal information is crucial for identifying individuals and ensuring effective patient communication. Recording contact numbers and residential addresses facilitates easy access and outreach when needed. Demographic data should be collected initially to avoid redundant registration in subsequent visits and to expedite patient acceptance and record management. The Women's Surgeons Association has identified certain demographic characteristics, such as low socioeconomic status and African-American ethnicity, as significant risk factors for preeclampsia (10, 20, 21).

5.2. Medical History of Patients

The medical history of patients is critical for understanding preeclampsia risk. Specific factors such as chronic hypertension, a history of previous preeclampsia, and multiple pregnancies are recognized risk indicators. Aziz et al. underscored the importance of factors like excess weight, previous preeclampsia, diabetes, multiple pregnancies, and history of abortions, aligning with the findings of the present study. Related research has emphasized the importance of capturing information such as systolic and diastolic blood pressure history, chronic hypertension, gestational diabetes, obesity, immune conditions, kidney disease, anemia, pregnancy-related vomiting, headaches, and migraines as essential components of a patient's medical history (19, 22, 23).

5.3. Laboratory Data

Laboratory data play a pivotal role in diagnosing preeclampsia. For instance, elevated creatinine levels above 1, combined with proteinuria, are significant risk indicators. Studies have highlighted the importance of laboratory metrics such as hemoglobin, uric acid, creatinine, and proteinuria. Jhee et al. emphasized the predictive value of laboratory data, including blood nitrogen and urea, serum creatinine, and the urine protein-to-creatinine ratio, in identifying preeclampsia risk (18).

5.4. Pregnancy-Related Data

Credible medical guidelines, including those from the American College of Obstetricians and Gynecologists, highlight factors such as gestational hypertension, a previous pregnancy with hypertension, multiple gestations, nulliparity, an interpregnancy interval of more than ten years, and the use of assisted reproductive technology as significant data items related to pregnancy. A related study examined the approach and strategies for prevention, care, and follow-up, emphasizing the importance of the type of pregnancy prevention method and its role in predicting preeclampsia (24). This aspect was also deemed significant in the current study, underscoring its importance in anticipating and managing preeclampsia.

5.5. Complications of Preeclampsia in Other Organs

The recording of thrombocytopenia and other complications arising in different organs due to preeclampsia is essential, as these complications can lead to the primary diagnosis. For instance, if a patient's blood pressure has not reached the severe preeclampsia stage but thrombocytopenia or visual disturbances are present, the diagnosis of preeclampsia can be established, prompting immediate emergency measures. A related study highlighted the importance of data such as neurological disorders and thrombocytopenia and their impact on predicting preeclampsia (25).

5.6. Warning Signs

Identifying warning signs is crucial for the rapid and timely diagnosis of preeclampsia. Early diagnosis is vital because preeclampsia can progress rapidly from mild to severe stages, potentially leading to serious complications. If these symptoms are recognized promptly, it is possible to prevent or at least slow the progression of the disorder (26, 27).

5.7. Medical Examinations

Regular antenatal care is essential for the early detection of preeclampsia. During these examinations, healthcare providers assess various indicators, such as swelling in the face and hands, which can signal preeclampsia. By routinely monitoring pregnant individuals for symptoms, healthcare providers can intervene quickly, improving outcomes for both the mother and the baby (28-30).

5.8. Lifestyle

While medical interventions play a crucial role in managing preeclampsia, recent research emphasizes the importance of lifestyle changes during pregnancy to reduce the risk of developing this condition. Regular physical activity, following recommended guidelines, can contribute to better health outcomes. Dietary control and stress management techniques such as meditation and yoga may also be beneficial (29-31).

5.9. Conclusions

In conclusion, identifying the information requirements for preeclampsia is an effective step toward designing more precise CDSS, which can improve their performance in health and prevention. By accurately determining the information requirements for these systems, the storage, retrieval, and especially data processing and information presentation in reports to women's health specialists will be more streamlined. Ultimately, by identifying essential information, a CDSS can support women's health specialists and assistive technologies in preventing and reducing the risk of the high-risk disorder, preeclampsia.

Acknowledgements

We would like to express our thanks and appreciation to all the specialists who assisted us in this research.

Footnotes

Authors' Contribution: Study concept and design: A. G. and N. A.; Acquisition of data: N. Kh. and A. G.; Analysis and interpretation of data: N. G., N. Kh., and N. A.; Drafting of the manuscript: N. Kh., N. A., and A. G.; Critical revision of the manuscript for important intellectual content: N. G. and V. Kh.; Statistical analysis: A. G. and N. Kh.; Administrative, technical, and material support: N. A. and N. Kh.; Study supervision: N. A. and A. G. All authors approved the final version of the manuscript.

Conflict of Interests Statement: The authors declare that this article has no conflicts of interest.

Data Availability: The dataset presented in this study is available upon request from the corresponding author during submission or after publication.

Ethical Approval: This study obtained ethical approval under the number IR.LUMS.REC.1402.175 from Lorestan University of Medical Sciences. This article is part of a master's thesis at the School of Allied Medical Sciences, Lorestan University of Medical Sciences.

Funding/Support: This study was supported by grant No. 1397-1-99-3271 as a master's thesis from Lorestan University of Medical Sciences.

Informed Consent: Informed consent was obtained from all participants.

References

1. Sarria-Santamera A, Lagana AS, Terzic M. Women's Health and Gynecology: Old Challenges and New Insights. *Int J Environ Res Public Health*. 2022;**19**(24). [PubMed ID: 36554470]. [PubMed Central ID: PMC9779633]. https://doi.org/10.3390/ijerph192416589.
2. Horsager R, Hoffman BL, Santiago-Muñoz PC, Rogers VL, Worley KC, Roberts SW. *Williams Obstetrics, 24th Edition, Study Guide*. New York, USA: McGraw-Hill Education; 2014.
3. Aramesh SH, Qaitasi A, Masnavi E, Qaitasi I, Hassanzadeh S. [Prevalence of Preeclampsia, Eclampsia and Related Factors in Pregnant Women Referred to Imam Sajjad Hospital in Yasuj in 2016]. *Armaghane Danesh*. 2020;**25**(1):129-39. FA. https://doi.org/10.52547/armaghanj.25.1.129.
4. English FA, Kenny LC, McCarthy FP. Risk factors and effective management of preeclampsia. *Integr Blood Press Control*. 2015;**8**:7-12.

[PubMed ID: 25767405]. [PubMed Central ID: PMC4354613]. https://doi.org/10.2147/IBPC.S50641.

5. Fox R, Kitt J, Leeson P, Aye CYL, Lewandowski AJ. Preeclampsia: Risk Factors, Diagnosis, Management, and the Cardiovascular Impact on the Offspring. *J Clin Med*. 2019;**8**(10). [PubMed ID: 31590294]. [PubMed Central ID: PMC6832549]. https://doi.org/10.3390/jcm8101625.
6. Melinte-Popescu AS, Vasilache IA, Socolov D, Melinte-Popescu M. Predictive Performance of Machine Learning-Based Methods for the Prediction of Preeclampsia-A Prospective Study. *J Clin Med*. 2023;**12**(2). [PubMed ID: 36675347]. [PubMed Central ID: PMC9865606]. https://doi.org/10.3390/jcm12020418.
7. Yerlikaya G, Akolekar R, McPherson K, Syngelaki A, Nicolaides KH. Prediction of stillbirth from maternal demographic and pregnancy characteristics. *Ultrasound Obstet Gynecol*. 2016;**48**(5):607-12. [PubMed ID: 27561693]. https://doi.org/10.1002/uog.17290.
8. Yu CK, Khouri O, Onwudiwe N, Spiliopoulos Y, Nicolaides KH; Fetal Medicine Foundation Second-Trimester Screening Group. Prediction of pre-eclampsia by uterine artery Doppler imaging: relationship to gestational age at delivery and small-for-gestational age. *Ultrasound Obstet Gynecol*. 2008;**31**(3):310-3. [PubMed ID: 18241089]. https://doi.org/10.1002/uog.5252.
9. Solomon CG, Seely EW. Preeclampsia -- searching for the cause. *N Engl J Med*. 2004;**350**(7):641-2. [PubMed ID: 14764924]. https://doi.org/10.1056/NEJMp038241.
10. Sadoughi F, Aminpour F. [How To Evaluate Health Information Systems: Evaluation Stages]. *Iran J Med Educ*. 2011;**10**(5):950-63. Perdisn.
11. Berner ES. *Clinical Decision Support Systems*. New York, USA: Springer; 2007. https://doi.org/10.1007/978-0-387-38319-4.
12. Sim LL, Ban KH, Tan TW, Sethi SK, Loh TP. Development of a clinical decision support system for diabetes care: A pilot study. *PLoS One*. 2017;**12**(2). e0173021. [PubMed ID: 28235017]. [PubMed Central ID: PMC5325565]. https://doi.org/10.1371/journal.pone.0173021.
13. Sutton RT, Pincock D, Baumgart DC, Sadowski DC, Fedorak RN, Kroeker KI. An overview of clinical decision support systems: benefits, risks, and strategies for success. *NPJ Digit Med*. 2020;**3**:17. [PubMed ID: 32047862]. [PubMed Central ID: PMC7005290]. https://doi.org/10.1038/s41746-020-0221-y.
14. Safdari R, Karami M, Mirzaee M, Rahimi A. [A Systematic Review Of Decision Support Systems: Effects On Health Care]. *Payavard Salamat*. 2013;**7**(1):56-70. FA.
15. Bui LN, Marshall C, Miller-Rosales C, Rodriguez HP. Hospital Adoption of Electronic Decision Support Tools for Preeclampsia Management. *Qual Manag Health Care*. 2022;**31**(2):59-67. [PubMed ID: 34048375]. [PubMed Central ID: PMC8626519]. https://doi.org/10.1097/QMH.0000000000000328.
16. Dalaba MA, Akweongo P, Aborigo RA, Saronga HP, Williams J, Blank A, et al. Cost-effectiveness of clinical decision support system in improving maternal health care in Ghana. *PLoS One*. 2015;**10**(5). e0125920. [PubMed ID: 25974093]. [PubMed Central ID: PMC4431831]. https://doi.org/10.1371/journal.pone.0125920.
17. Liu M, Yang X, Chen G, Ding Y, Shi M, Sun L, et al. Development of a prediction model on preeclampsia using machine learning-based method: a retrospective cohort study in China. *Front Physiol*. 2022;**13**:896969. [PubMed ID: 36035487]. [PubMed Central ID: PMC9413067]. https://doi.org/10.3389/fphys.2022.896969.
18. Jhee JH, Lee S, Park Y, Lee SE, Kim YA, Kang SW, et al. Prediction model development of late-onset preeclampsia using machine learning-based methods. *PLoS One*. 2019;**14**(8). e0221202. [PubMed ID: 31442238]. [PubMed Central ID: PMC6707607]. https://doi.org/10.1371/journal.pone.0221202.
19. Wang G, Zhang Y, Li S, Zhang J, Jiang D, Li X, et al. A Machine Learning-Based Prediction Model for Cardiovascular Risk in Women With Preeclampsia. *Front Cardiovasc Med*. 2021;**8**:736491. [PubMed ID: 34778400]. [PubMed Central ID: PMC8578855]. https://doi.org/10.3389/fcvm.2021.736491.
20. World Health Organization. *Developing health management information systems : a practical guide for developing countries*. Manila: WHO Regional Office for the Western Pacific; 2004. vi p. 54 p.
21. Mensah M, Adjei E. Demographic factors affecting the commitment of medical records personnel at the Korle-Bu Teaching Hospital in Ghana. *Inform Dev*. 2014;**31**(5):451-60. https://doi.org/10.1177/0266666914523019.
22. Aziz F, Khan MF, Moiz A. Gestational diabetes mellitus, hypertension, and dyslipidemia as the risk factors of preeclampsia. *Sci Rep*. 2024;**14**(1):6182. [PubMed ID: 38486097]. [PubMed Central ID: PMC10940289]. https://doi.org/10.1038/s41598-024-56790-z.
23. Maric I, Tsur A, Aghaeepour N, Montanari A, Stevenson DK, Shaw GM, et al. Early prediction of preeclampsia via machine learning. *Am J Obstet Gynecol MFM*. 2020;**2**(2):100100. [PubMed ID: 33345966]. https://doi.org/10.1016/j.ajogmf.2020.100100.
24. Roberts JM, King TL, Barton JR, Beck S, Bernstein IM, Buck TE, et al. Care plan for individuals at risk for preeclampsia: shared approach to education, strategies for prevention, surveillance, and follow-up. *Am J Obstet Gynecol*. 2023;**229**(3):193-213. [PubMed ID: 37120055]. https://doi.org/10.1016/j.ajog.2023.04.023.
25. Payne BA, Hutcheon JA, Ansermino JM, Hall DR, Bhutta ZA, Bhutta SZ, et al. A risk prediction model for the assessment and triage of women with hypertensive disorders of pregnancy in low-resourced settings: the miniPIERS (Pre-eclampsia Integrated Estimate of RiSk) multi-country prospective cohort study. *PLoS Med*. 2014;**11**(1). e1001589. [PubMed ID: 24465185]. [PubMed Central ID: PMC3897359]. https://doi.org/10.1371/journal.pmed.1001589.
26. Hackeloer M, Schmidt L, Verlohren S. New advances in prediction and surveillance of preeclampsia: role of machine learning approaches and remote monitoring. *Arch Gynecol Obstet*. 2023;**308**(6):1663-77. [PubMed ID: 36566477]. [PubMed Central ID: PMC9790089]. https://doi.org/10.1007/s00404-022-06864-y.
27. Wang J, Yang Z. Key points to early action for preventing and monitoring the syndrome of preeclampsia. *Maternal Fetal Med*. 2021;**3**(2):81-6.
28. Bibbins-Domingo K, Grossman DC, Curry SJ, Barry MJ, Davidson KW, Doubeni CA, et al. Screening for Preeclampsia: US Preventive Services Task Force Recommendation Statement. *JAMA*. 2017;**317**(16):1661-7. [PubMed ID: 28444286]. https://doi.org/10.1001/jama.2017.3439.
29. Marin I, Vasilateanu A, Pavaloiu B, Goga N. User requirements and analysis of preeclampsia detection done through a smart bracelet. *arXiv*. 2021;**Preprint**.
30. Li S, Wang Z, Vieira LA, Zheutlin AB, Ru B, Schadt E, et al. Improving preeclampsia risk prediction by modeling pregnancy trajectories from routinely collected electronic medical record data. *NPJ Digit Med*. 2022;**5**(1):68. [PubMed ID: 35668134]. [PubMed Central ID: PMC9170686]. https://doi.org/10.1038/s41746-022-00612-x.
31. Rasouli M, Pourheidari M, Hamzeh Gardesh Z. Effect of Self-care Before and During Pregnancy to Prevention and Control Preeclampsia in High-risk Women. *Int J Prev Med*. 2019;**10**:21. [PubMed ID: 30820308]. [PubMed Central ID: PMC6390427]. https://doi.org/10.4103/ijpvm.IJPVM_300_17.