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Synopsis of the existing preeclampsia detention tools and devices

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Abstract: *Preeclampsia is a serious pregnancy-related condition characterized by high blood pressure and potential damage to organs, most commonly the liver and kidneys. Early detection and prediction are critical for managing the condition and reducing maternal and fetal morbidity and mortality. A range of devices and tools are employed to monitor and predict the onset of preeclampsia in pregnant women. These include traditional methods like blood pressure monitors and urine protein dipsticks, as well as advanced technologies such as Doppler ultrasound and bioimpedance analysis. Recent developments in biomarker discovery have led to the use of specific blood tests that measure levels of angiogenic factors, which are indicative of preeclampsia risk. Additionally, wearable technologies and remote monitoring systems have emerged, enabling continuous tracking of vital signs and providing real-time data analysis to predict the condition. Machine learning models are also being integrated into prediction algorithms, enhancing the accuracy of preeclampsia forecasts by analyzing a combination of clinical, demographic, and biochemical data. These tools, combined with regular prenatal care, form a comprehensive approach to the early detection and management of preeclampsia, ultimately improving outcomes for both mothers and their babies.*

Keywords: Preeclampsia, hypertension, pregnancy, Eclampsia, health system, antenatal care, proteinuria

INTRODUCTION

Preeclampsia is a major contributor to global maternal morbidity and mortality, affecting between 2% and 8% of pregnancies worldwide. It not only leads to immediate complications like acute kidney injury, liver damage, seizures, stroke, and coagulopathy but also increases the risk of developing chronic conditions such as essential hypertension and cardiovascular disease later in life [1]. Over the past three decades, the global incidence of preeclampsia has risen by 11%, making it the leading cause of maternal mortality in many low-resource settings. This increase may be linked to the growing prevalence of risk factors, including extremes in reproductive age, multiple pregnancies, and medical conditions like chronic hypertension, obesity, and diabetes [2].

Globally, the progression from preeclampsia to eclampsia has significantly declined, largely due to increased utilization of antenatal care, higher rates of in-facility deliveries, and better access to magnesium sulfate. However, these improvements in management have not consistently led to better clinical outcomes in low- and middle-income countries (LMICs) [3]. Over 99% of maternal deaths from hypertensive disorders of pregnancy occur in LMICs, with a higher incidence of progression to eclampsia, and nearly 50% of eclamptic seizures occurring outside of a hospital setting. In Uganda, the incidence of hypertensive disorders in pregnancy is estimated at 25%. despite advancements in clinical protocols and greater access to essential medications like antihypertensive and magnesium sulfate, rates of eclampsia remain significantly higher than in high-income countries, and neonatal outcomes are poor [4]. Reports from two major tertiary-level hospitals indicate that hypertensive disorders have surpassed hemorrhage as the leading cause of maternal mortality [5]. Challenges unique to managing preeclampsia in LMICs contribute to these disparities, including low levels of health literacy, poor antenatal care attendance, and limited healthcare resources [6]. With extensive patient care experiences across various clinical training sites, obstetric doctors are well-positioned to discuss the daily challenges they face at the patient, provider, and systems levels in caring for patients with preeclampsia.

In resource-limited countries, early detection of preeclampsia is often hindered by limited access to skilled healthcare providers and equipment for monitoring blood pressure and urine protein levels. A fundamental issue, common in both developing and developed countries, is that blood pressure is frequently measured and recorded inaccurately [7]. Moreover, blood pressure equipment requires proper maintenance to function correctly. For a potentially illiterate woman to use this equipment in her village, the device is often too expensive and demands skills such as numeracy and record-keeping, which may be beyond her capacity.

Diagnosing proteinuria in low-resource settings presents significant challenges. Methods such as using dipsticks or heating a urine sample over a Bunsen burner can be too costly, especially for repeated tests, and are often inaccessible to pregnant women. Implementing these methods also faces several hurdles, including cultural resistance to collecting samples and the technical skills needed to interpret the results [5]. Using edema as an indicator might involve monitoring changes in the size of the hands or face over time with a tape measure and record book. However, expecting a pregnant woman in a low-resource environment to consistently read numbers and maintain written records is often unrealistic.

The exact cause of preeclampsia remains debated and is likely due to a complex interaction of maternal, genetic, and immune factors. Evidence suggests that, particularly in early-onset preeclampsia, the pathological mechanisms originate at the fetal-maternal interface [6]. In pregnancies that develop preeclampsia, cytotrophoblasts fail to transform into their endothelial subtype, resulting in inadequate remodeling of the spiral arterioles. This leads to a low-flow, high-resistance circulation.

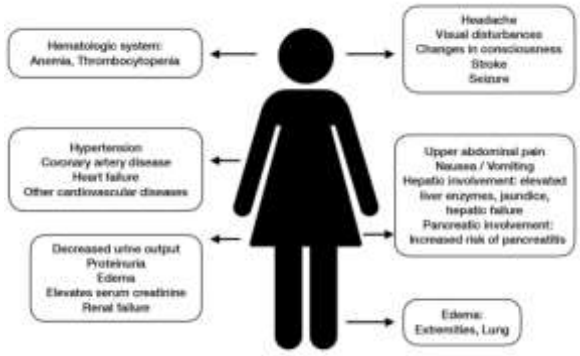

Figure 1: Systematic occurrence of preeclampsia

Recent advancements in preeclampsia research have led to the identification of novel markers that not only help detect the disease earlier but also hold promise in enhancing our understanding of it [8]. These emerging markers include a range of biological molecules, specific proteins, micro-RNAs, and metabolites. Some of the tools and devices used for the diagnosis are discussed below:

The Momedemameter

The general principle of this method is to have each pregnant woman, early in pregnancy, fitted, on either her wrist or ankle, with a detection band, which is set to allow a preset expansion percentage (e.g., expansion by 5%). When edema causes the body part to swell to fit the detection band snuggly, the pregnant mother knows that she should seek medical assistance. The length of the detection band is set by one of a set of calibration bands placed on the wrist or ankle of the patient at a clinic or by an iterant health care worker [9]. The time point in pregnancy chosen to do this fitting is between the 16th and 24th weeks, when the diagnosis of preeclampsia is uncommon. This technique used Edema as a basis diagnosis which is very limiting, Although edema occurs frequently in the genesis of the syndrome, and was an original component of the syndrome definition, it is not unique to the syndrome of preeclampsia. Edema is, nonetheless, an indicator of potential pregnancy complications. Moreover, it is more easily clinically monitored than blood pressure or proteinuria, especially in low-resource environments where skilled healthcare providers with appropriate technology are not readily accessible.

Test Strips

This method was developed by students from Makerere University, they used two protein biomarkers activin A and inhibin A which elevate dramatically during early onset of preeclampsia, even before the woman experiences symptoms [10]. So, they set out to develop a home-based diagnostic test strip that can instantly detect these biomarkers in a woman's urine, thereby empowering and educating women so they know when to seek medical care before their complication becomes severe.

Digital tools

Digital Health initiative such as telemonitoring was applied in Parkinstan to support women at risk of developing pre-eclampsia by close monitoring of blood pressure at home for earliest signs. The use of telemonitoring leads to early detection of pre-eclampsia and the required need for treatment and admission of women with pre-eclampsia [11]

. South Africa implemented mobile health initiatives such as Mom-Connect to improve foetal-maternal well-being at home by targeted communications to pregnant women with various disorders including pre-eclampsia.

Machine learning

In present studies, researchers devised and validated the MERLIN machine learning tool to estimate preeclampsia risk throughout pregnancy. The team developed a combination of blood pressure measurements, ICD codes, and laboratory results to determine the preeclampsia phenotype in the datasets [12]. Linear regression, xgboost random forest classifiers, deep neural networks (DNN), and elastic net models were used to develop the tool and evaluate its performance.

Clinical Tools

A new first-trimester screening algorithm has been developed and validated to predict preterm preeclampsia. It combines mean arterial blood pressure, Doppler ultrasound measured maternal uterine artery resistance, and levels of circulating Placental Growth Factor (PlGF). This test is superior in predicting preterm preeclampsia compared to clinical risk factors alone [13]. It correctly detects 82% of cases – doubling the detection rate achieved by application of clinical factors using the NICE guidelines. When used to identify who should be offered aspirin to prevent preeclampsia, it significantly reduces preterm preeclampsia. In turn, this reduces hospital costs and reduced financial and long-term human costs associated with preterm birth [14]. Several international societies now recommend first trimester combination screening for preterm preeclampsia. However, the costs of implementing the test (given the ultrasound expertise and assays to measure PlGF required) have meant implementation has not been universal.

Bioimpedance Analysis

Bioimpedance analysis (BIA) is a non-invasive technique used to assess body composition, particularly fluid status, by measuring the resistance (impedance) of body tissues to a small, safe electrical current. In the context of preeclampsia, BIA is valuable for evaluating and monitoring fluid balance, which is often disrupted in this condition [15].

Preeclampsia is associated with fluid retention and edema, resulting from endothelial dysfunction and increased vascular

permeability. BIA can detect these changes by assessing the distribution of extracellular and intracellular fluids, providing critical insights into the severity of the condition [16]. By monitoring these parameters, BIA helps healthcare providers assess the progression of preeclampsia, guide therapeutic interventions, and evaluate the effectiveness of treatments aimed at reducing fluid overload.

Moreover, BIA can be used as part of a broader monitoring strategy in conjunction with other diagnostic tools to provide a more comprehensive understanding of a patient's condition. The use of BIA in preeclampsia management highlights its potential to enhance clinical decision-making by offering precise, real-time data on fluid status, which is crucial in managing the risks associated with this condition.

Conclusion

The early detection and prediction of preeclampsia are vital for ensuring the health and safety of both pregnant women and their babies. A combination of traditional monitoring methods, advanced diagnostic tools, and emerging technologies offers a comprehensive approach to managing this condition. Blood pressure monitors and urine protein tests remain foundational in clinical settings, while Doppler ultrasound and bioimpedance analysis provide more detailed insights into maternal and fetal health. The introduction of biomarker-based blood tests has significantly enhanced the ability to predict preeclampsia, allowing for earlier intervention. Furthermore, wearable devices and remote monitoring systems offer continuous surveillance, and machine learning models are pushing the boundaries of predictive accuracy by integrating diverse data sources. Together, these tools enable healthcare providers to better anticipate and respond to the risks of preeclampsia, leading to improved outcomes and reduced complications during pregnancy. Continued advancements in these technologies and design hold promise for even more effective management of preeclampsia in the future.

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