Blood Pressure Measurement

Technology Opportunity Assessment

Prepared for the Merck for Mothers Program
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Summary

Positive maternal health outcomes for women with preeclampsia/eclampsia depend on timely identification of hypertension using an accurate blood pressure measurement device (BPMD). The detection of hypertension is often missed because suitable, accurate, and reliable BPMDs are not available, and training in the skills and methods necessary to get a reliable measurement is limited.

Statement of Need

Preeclampsia (PE) is a life-threatening disorder that only occurs during pregnancy, childbirth, and the postpartum period and is characterized by high blood pressure (BP) (hypertension) and protein in the urine (proteinuria). Convulsions (fits) with signs of PE indicate eclampsia, although convulsions occasionally occur in the absence of hypertension with proteinuria. PE and eclampsia (PE/E) are among the leading causes of maternal death and disability worldwide. The World Health Organization (WHO) estimates that PE/E account for at least 16% of maternal deaths in settings with low resources that lack the skilled providers and facilities required for prevention, identification, and management of the condition. In most countries, PE/E rank second only to hemorrhage as specific, direct causes of maternal death. The risk of PE/E varies greatly depending on where a woman lives; the risk that a woman in a low-resource country will die of PE/E is approximately 300 times greater than that for a woman in a high-resource country.

Positive maternal and perinatal outcomes for women with PE/E depend on how soon the condition is identified and how quickly the woman has access to a treatment package including in-patient monitoring, anticonvulsive and antihypertensive therapy, optimal timing of childbirth, and skilled attendance at birth. Secondary prevention of PE/E has focused on antenatal screening for high BP and proteinuria as part of focused antenatal care (ANC). The decrease in maternal mortality and serious morbidity results mainly from early identification of women with PE, followed by close clinical and laboratory monitoring to prevent, recognize, and appropriately manage disease progression.

*Focused ANC is evidence-based, goal-directed care that is tailored to the gestational age of pregnancy and individualized to each woman. It emphasizes quality of visits over quantity of visits and is conducted by a skilled health care provider. Goals of focused ANC include early detection and treatment of complications, prevention of problems, birth preparedness/complication readiness, and the promotion of healthy practices to help ensure a positive health outcome for the woman and her baby. Focused ANC is provided through a woman-centered approach that values the dignity and value of each woman and her family.
While obtaining BP during routine antenatal and postpartum care seems relatively simple, a WHO expert committee identified that many providers fail to identify hypertension, largely because of the unavailability of suitable BP measurement devices (BPMD) and limited attention paid to the techniques and procedures necessary to obtain accurate BP. These WHO experts and Villar, et al. identified the following barriers to accurate and affordable BP measurement, particularly in low-resource settings:

- The absence of accurate, easily obtainable, inexpensive devices for BP measurement.
- Marketing of non-validated BPMD.
- High cost of BPMD given the limited resources available.
- Limited awareness of the problems associated with conventional sphygmomanometers, such as the need for calibration, loss of accuracy over time, inaccuracies associated with deflation rate, and “under-cuffing” or “over-cuffing” the patient.
- A general lack of trained manpower and limited training of skilled personnel.
- Use of stethoscopes with long tubing that reduces the quality of sound transmission.
- Limited awareness of the problems associated with automated BPMD, including the use of oscillometric measurement rather than Korotkoff sounds and the need for accuracy testing before use.3,4

In addition to these barriers, most BPMD require the presence of a health care provider who can read and interpret the results and manipulate a stethoscope, thus limiting BP measurement access to health care facilities staffed by qualified health care professionals.

There is clearly a need to develop either a simple calibration tool that can improve the accuracy of currently available BPMD or a BPMD that is accurate, simple to use, simple to calibrate, affordable, robust, and easily available worldwide.† To impact morbidity and mortality from PE/E, access to BP measurement should be extended to the community level, thus greatly improving identification of women with hypertension and, by consequence, increasing the woman’s chance that she will have access to the treatment package, ultimately increasing the likelihood that she and her baby will survive.

† A group of WHO experts made the following general recommendations for a BPMD for low-resource settings: (1) BPMD should be accurate, simple to use, affordable, and easily available worldwide; (2) Given the serious inherent inaccuracy of the auscultatory technique, validated and affordable electronic devices that have the option to select manual readings are the preferred option; (3) In light of the toxicity of mercury, it is recommended that mercury BPMD be gradually phased out in favor of affordable, validated, professional electronic devices as these become available. However, if it is difficult to replace mercury devices, they should be serviced and calibrated at regular intervals; (4) In circumstances where aneroid devices are already being used, provided they have been shown to be accurate not only at the time of manufacture but also after a period of time in use, they should be calibrated at regular intervals (e.g., every 6 months); (5) Regardless of the type of BPMD, appropriate cuff sizes should be available; (6) If the BPMD uses the auscultatory technique, users should receive appropriate training and be assessed periodically for accuracy.
Technology Solutions Landscape

Current options for BPMD include mercury sphygmomanometers, aneroid manometers, semiautomatic devices, and fully automatic electronic devices. Parati, et al. noted that “In spite of the accuracy and affordability of mercury sphygmomanometer devices, they have a limited future due to increasing concerns about the toxicity of mercury for users and/or service personnel and for the environment in general. Some countries are recommending that mercury sphygmomanometers be replaced, while others have banned the use of mercury altogether.”

WHO has stated that “As mercury sphygmomanometers are removed from clinical practice, there is a tendency to replace them with aneroid devices on the false assumption that they can be interchanged because both can be used to measure BP by means of the auscultatory technique. However, aneroid devices are subject to terminal digit bias (reader error), and the accuracy of aneroid devices can be poor as they can be knocked out of calibration easily. Given the inaccuracy of the auscultatory technique, irrespective of the sphygmomanometer used, there is a need to replace it with accurate automated methods of measurement. An accurate automated sphygmomanometer eliminates errors of interpretation, observer bias, and terminal digit preference. Moreover, elaborate training in using the automated device is not required.”

WHO furthermore acknowledges that “A transition toward automated blood pressure measurement is under way. However, the advent of accurate automated devices as an alternative to the mercury manometer, although welcomed, is not without limitations.” Automated devices are notoriously inaccurate, although more accurate devices are now appearing on the market. Villar, et al. uncovered that “there are at least 15 studies relating to validation of automated devices in pregnancy and PE. Two of these involve intra-arterial data and nine include data from women with PE. In total, ten studies have sufficient data to perform a meta-analysis. The results of these studies are shown in Table 1.”

Table 1. Validation of automated blood-pressure devices: Meta-analysis of data from 15 trials.

<table>
<thead>
<tr>
<th>Blood pressure level</th>
<th>Mercury device</th>
<th>Intra-arterial device</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blood pressure difference (S.D.)</td>
<td>Blood pressure difference (S.D.)</td>
</tr>
<tr>
<td></td>
<td>Pregnant women</td>
<td>Pre-eclamptic women</td>
</tr>
<tr>
<td>Systolic (mmHg)</td>
<td>–1.13 (5.80)</td>
<td>–4.60 (8.04)</td>
</tr>
<tr>
<td>Diastolic (mmHg)</td>
<td>–1.20 (6.03)</td>
<td>–5.16 (7.19)</td>
</tr>
</tbody>
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‡ The dabl® educational trust website [http://www.dableducational.org/sphygmomanometers/devices_1_clinical.html#ManualTable] maintains an up-to-date landscape of currently available mercury, aneroid, and non-mercury manual BPMD, automated devices for clinical use, and finger devices for clinical measurement. The landscape includes validation status and recommendations for their use.

§ Users of automated devices should be aware that devices validated against international standards can have 25% of measurements differing by more than 10 mmHg from measurements by trained observers. Thus, device validation does not guarantee reliable measurement in all patients.
Villar, et al. assess from this meta-analysis that “Average errors are not large, and although these devices do under-record in preeclampsia, the degree of error does not preclude their use in clinical practice. Automated devices will inevitably be increasingly used, and clinicians must ensure they have been assessed for use in pregnancy.”

**Gap Analysis**

There is a need to increase the supply and distribution of validated automated BPMD that are affordable for low-resource settings. Additional important considerations in the selection of a device are durability, servicing requirements, and power or battery requirements. In light of the difficulties associated with frequent battery replacement, semiautomatic devices appear to be more suitable than fully automatic devices, particularly in low-resource settings. Semiautomatic devices are battery powered; however, they do not require frequent battery replacement since the cuff is inflated manually using a hand bulb.

In 2002, WHO established a committee to develop technical specifications for an accurate and affordable BPMD for clinical use in low-resource countries. The objectives of the project were to elaborate on the preferred characteristics and to develop technical specifications for such a device. A challenge was issued by WHO to industry stipulating that devices fulfilling the specifications must be subjected to independent validation according to the European Society of Hypertension International Protocol (ESH-IP). Having fulfilled this requirement, the device then had to undergo testing in field conditions according to a predetermined protocol in clinical and environmental circumstances that would reflect the ultimate circumstances of use.

Out of three devices tested,** only one device, the Omron HEM-SOLAR, fulfilled the validation criteria of the international protocol for systolic BP.** The device also performed well in field testing on 716 subjects in three centers in Uganda and Zambia where health care workers preferred it to the mercury sphygmomanometer. These field tests demonstrated that the device fulfilled criteria for systolic but not diastolic BP measurement. Training took about 15 minutes, and some 85 percent of health care professionals rated the solar device as “good” or “very good,” with 97 percent recommending its use. The Omron HEM-SOLAR was favored over the mercury sphygmomanometer by both patients and investigators. The device can run on batteries as well as solar power. A technical analysis of the device design and construction has been completed. As Parati, et al. proposed, “considering the accuracy, robustness, relatively low cost, operational simplicity, and advantages such as solar power, the Omron HEM-SOLAR is likely to be a valuable device for improving BP measurement in low-resource settings with non-physician health care workers.”

The recent successful field evaluation of the Omron HEM-SOLAR demonstrates that oscillometric devices are becoming more accurate, and the recently revised ESH-IP standards, by acknowledging

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** Three devices were tested from manufacturers A&D Instruments Ltd, Microlife, and Omron.
this trend, will allow more accurate devices to enter the market. However, as Amoore stated, “the indirect nature of oscillatory BP measurement poses particular problems for ensuring accuracy. Critical assessment has done much to improve standards, but a solid theoretical understanding of the oscillometric technique has not been formulated, and further work is required.”

Three additional BPMD are notable: the MicroLife BP3AS1-2, Accoson Greenlight 300, and the Tensoval duo control device. The MicroLife BP3AS1-2 was designed to conform to most of the WHO recommended specifications for BPMD in low-resource settings. It is regulatory cleared, commercially produced, and available in certain markets but not widely available for use in low-resource settings. The Accoson Greenlight 300 is a manual, self-calibrating, mercury-free auscultatory device. The benefit is that the device obviates the need for frequent calibrations and ensures accuracy by eliminating sensor drift.

Another device, the Tensoval duo control device produced by Hartmann-Rico uses both auscultatory and oscillometric technology to determine BP. By using two modes, the device can provide more accurate readings in challenging subset populations (such as pregnant women), and it is marketed for use in patients with various types of cardiac arrhythmia and hypertension. Both the Accoson and Tensoval devices have been validated to the British Hypertension Society (BHS) protocols, and though they are currently priced for developed markets, their innovative approaches to BP measurement deserve additional investigation as these tools have features that may be very beneficial to PE diagnostics in low-resource settings.

It is important to note that these devices have not yet been tested with pregnant women. Given that a number of studies have demonstrated that oscillometric monitors may produce inaccurate measurements in patients with heart and circulation problems, including PE, it is difficult to recommend their use in pregnant women without further research.

In addition, the WHO specification for low-cost BPMD may lead to lower quality sensors that are more subject to drift and errors associated with mishandling. Thus, the importance of frequent calibration cannot be underestimated. That said, adherence to a calibration schedule and equipment maintenance are general shortcomings in most low-resource settings; thus, there is a trade-off between cost of the device and accuracy when normal calibrations cannot be guaranteed. In conjunction with advancing novel BPMD technologies, there is a need to solve the calibration challenge by developing technologies that need less frequent calibration or none at all and by developing calibration standards and processes that are low cost and require minimal skills to implement.

†† The OMRON-MIT, is the only automated oscillometric device that has proven to be accurate for BP measurement in PE according to the BHS protocol in pregnancy, suggesting that inflationary oscillometry algorithms may effectively correct the error associated with oscillometric devices in PE.
Investment Opportunity

PATH proposes that an initiative for BP measurement be centered on the following broad strategies:

- Evaluate the leading BPMD technologies for use in developing countries in populations of pregnant women as soon as possible. Conduct a validation study according to the same rigorous protocol that was drawn up by the WHO committee specifically to test the performance and robustness of devices in low-resource settings and in accordance with BHS protocols. Provide a detailed assessment on the performance of the devices in pregnant women in field-test conditions.

- Invest in upstream technologies that improve accuracy and ease of use and reduce calibration requirements for BP measurement in low-resource settings. For example, the Omron HEM-SOLAR is validated by WHO, yet fails to meet the most stringent diastolic accuracy requirements of the BHS protocol.7

- Leverage existing state-of-the-art technologies to build the foundation for broader, longer-term uptake while working to achieve quick results in a few targeted countries through the initiation of a number of cross-cutting activities. If current technologies prove successful and are validated for use in populations of pregnant women, it will be important to stimulate demand in the short term by investing in medium- to large-scale evaluations and introduction of validated innovative technologies. These technologies should be introduced into two to four early-adopter countries through broad collaborations with ministries of health, nongovernmental organizations, and other key stakeholders. This will demonstrate the impact of these novel technologies on PE/E diagnosis and outcomes, create country/regional champions for the products, and provide near-term sales for current BP measurement producers. These introductions should leverage and even accelerate existing strategies to prevent, identify, and manage PE/E.


Reference