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## Personalized solutions for menopause through artificial intelligence: Are we there yet?

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Artificial intelligence can not only mimic but also greatly extend human intelligence. Machine learning and in particular deep learning models based upon artificial neural networks can draw upon diverse data that include clinical images and medical notes, as well as sensor-generated and genomic data. Such models can iteratively learn from large clinical databases and bring to bear the expertise of multiple medical specialties upon the data of individuals. Thus can medical decisions and personalized therapy for a single patient be informed by vast, collective experience [1].

Artificial intelligence (AI) methods and algorithms are being applied in varying ways across clinical and research domains. Yet machine learning (ML) has only begun to be applied to the menopausal transition. The end of a woman's fertility is a physiological state that is part of aging, and it is accompanied by a myriad of symptoms that include hot flashes, disrupted sleep, loss of energy, anxiety, and feelings of sadness and loss. These can transition to pathological phenomena such as incremental bone loss, diabetes, and cardiovascular disease and mortality. The complexity of menopause challenges general practitioners, gynaecologists, and women's health practitioners to provide comprehensive care [2].

By affording the analysis of very large amounts of clinical data, AI could improve the performance of diagnostic and prognostic models for the identification of health issues related to menopause and women at risk of developing complications, and assist physicians in the management of symptoms and health outcomes. ML could have a great impact upon the burden menopause places on health systems, the economy, and society. Although the implementation of AI is in an early phase, conditions such as osteoporosis that are prominent during and after menopause are being approached with deep learning (DL) models. Several studies have used a variety of neural network architectures using advanced algorithms and input parameters to identify groups at risk for osteoporosis, and positive results have been obtained with sensitivity values between 81 and 91% [2]. Image identification and recognition has also improved through the combination of bone density indicators and several texture parameters by models using feed forward neuronal networks, probabilistic neural networks, learning vectors quantification, and support vector machines (SVMs), which could potentially automate the diagnosis of osteoporosis and risk of fracture [2].

Machine learning also has shown promising results diagnosing menopause symptoms. In thirty-one women with hot flashes, applying SVMs improved the performance of sternal skin conductance in detecting hot flashes with a sensitivity of 87% and specificity of 97% [3]. The use of artificial neural networks for the screening of endometrial cancer in postmenopausal women achieved a sensitivity of 86% and specificity of 83% [4]. By bringing together clinical, genetic, and lifestyle data, AI can also improve personalized treatment in menopause. Barack et al., developed a computerized hybrid decision-making system to assist physicians by combining a clustering algorithm with knowledge-based algorithms to recommend hormone therapy for peri- and postmenopausal women [5].

Limited use has been made of AI in the study of cardiovascular risk factors of menopausal women that affect long-term health, survival, and quality of life. Šabanović et al., combined methods that included data mining and decision model trees in the analysis of clinical data

to evaluate and revise the standard definition of metabolic syndrome and the recognition of high cardiovascular risk among women who have hypertension and metabolic syndrome [6]. Gorodeski et al., implemented a random survival forest model to analyse electrocardiograms (ECGs) and all-cause mortality in 33,144 postmenopausal women and identified 20 variables that independently predict long-term mortality, 14 of which were ECG biomarkers [7].

Even though there has been progress in the application of AI to the study of women's health during and after the menopausal transition, there is not yet evidence of its application in clinical practice. Translating AI to clinical care will require two lines of development. First, our understanding, identification, and measurement of mechanisms underlying menopausal metabolic traits must advance to get optimal input datasets. Second, robust algorithms and systems are needed along with access to larger datasets within an ethical framework that guarantees privacy and data protection. This has special importance for the application of DL models, which allow extraction of features and patterns that expose underlying, relevant characteristics through training with a large amount of data.

We close with a cautionary note. AI is far from being perfected, and even the most sophisticated ML methods will be only as good as the data upon which they are trained. And in women's health, high quality clinical data that include detailed information on all life stages and women's diversity and outcomes are essential. At the same time, research must be cautious with the introduction of historical data because algorithms can readily learn what health professionals do, which includes their mistakes, and they just as easily can incorporate biases induced by health systems inefficiencies [1]. Despite their empirical capabilities, ML models can be inexplicit and difficult to relate to existing biological and medical knowledge [8]. Therefore, it is important to understand that AI algorithms can assist and facilitate the work of health professionals and make them better, but cannot replace them. These limitations should be carefully studied and understood to ensure that the promise of artificial intelligence is adequately developed and used to help bridge the gap from usual care to precise care and personalised prevention and treatment.

**Contributors**

Zayne Milena Roa Diaz drafted the editorial.

Taulant Muka conceived and drafted the editorial.

Oscar H. Franco conceived the editorial.

All authors contributed to the critical revision of the editorial and approved the final version.

**Conflict of interest**

The authors declare that they have no conflict of interest.

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