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Editorial

Bayes' theorem and its application to cardiovascular nursing

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Nurses often have to make clinical decisions for complex problems while working in conditions of uncertainty and unpredictability. This decision-making is often based on best estimates in the light of available evidence.[1,2] Moreover, nurses are increasingly asked, for instance, to order and interpret diagnostic tests, making it essential for them to understand the importance of predicting the probability of particular outcomes.

Probabilities represent chance, or a numerical measure of the uncertainty associated with an event or events. The probabilistic approach provides information about the degree of uncertainty of a particular outcome such as a diagnosis or test result. Thus, Bayesian statistics can play an important role in clinical nursing judgments and decision making.[3,4]

Bayes' theorem (law or rule) describes the probability of an event based on prior knowledge of conditions that might be related to the event. For example, if an acute coronary syndrome (ACS) is related to age, then, using Bayes' theorem, a person's age can be used to more accurately assess the probability that they have ACS, compared to the assessment of the probability of ACS made without knowledge of the person's age.

Bayes' theorem is named after Reverend Thomas Bayes (1701–1761), an English statistician, philosopher and Presbyterian minister, who first provided an equation that allows new evidence to update beliefs. Bayes' theorem is stated mathematically as the following equation:[5,6]

$$P(A \mid B) = \frac{P(A \cap B)}{P(B)} = \frac{P(A) * P(B \mid A)}{P(B)}$$

where A and B are events and $P(B) \neq 0$.

- $P(A)$ and $P(B)$ are the probabilities of observing A and B without regard to each other.
- $P(A \mid B)$ is the probability of observing event A given that B is true.
- $P(B \mid A)$ is the probability of observing event B given that A is true.

Bayesian modelling[7] and data analysis[8] are being used widely, including in clinical trials and health-care evaluation.[9] However, there is a comparative paucity of studies using this approach in nursing. For example, although the European Journal of Cardiovascular Nursing recently published several studies on long-term follow-up and prediction of outcomes,[10–12] none used a Bayesian approach. Examples of studies that have used a Bayesian approach include those studying outcomes in very large and complex datasets,[13] assessing the relationship between in-hospital and/or unplanned readmissions and nurse staffing variables,[14] estimating the true probability of a nursing diagnosis[15] and measuring equivalence between two rating scales.[16] Some pertinent examples of the diverse application of the approach to cardiovascular nursing include estimating coronary heart disease risk among asymptomatic adults[17] and estimating the efficacy of T'ai Chi as a case study.[18]

Innovation in the application of Bayesian approaches to cardiovascular and health data more broadly continues apace. Important developments in statistical computing programs represents a significant enabler in the application of Bayes' theorem to pertinent clinical and research questions of pressing relevance to cardiovascular nursing. Given that nurses are in a proximal and temporal advantageous position with cardiovascular patients to assess and ascertain relevant information to inform suitable 'priors' for use within the application of Bayesian approaches, the use and adoption of this approach represents a significant opportunity to enhance patient care

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through maximising the broader concept of 'evidence' within informing evidence-based practice. Useful data that may inform 'priors' includes that of a relevant clinical, psychological, social, biological and epidemiological nature to provide a more comprehensive approach to predictive modelling.

Translation of this additional information into the clinical setting could, potentially, represent a step-change in the paradigms by which cardiovascular care is defined and delivered. This presents a challenge to the perspective that cardiovascular disease diagnosis, treatment and intervention may be compartmentalised and defined by a limited number of (predominantly) clinical parameters. It is recognised that contemporary approaches to cardiovascular care within which most nurses will be working will be medically-focused and defined within a robust, but often inflexible, medical paradigm. This rationale is arguably based on the efficacy of a limited range of treatment interventions which are applied to a limited range of cardiovascular patient groups, for example, broad brushstroke categories such as myocardial infarction, heart failure and refractory angina. This presents enormous translational problems, in terms of both evidence and practice to, for example, patients with complex comorbidity where cardiovascular insult is just one part of the jigsaw of a far more complex whole[19] or those patients presenting with extremely rare forms of disease with associated cardiovascular pathology.[20] The general approach often taken in these circumstances is to translate more or less directly established practice that has been shown to be efficacious in larger groups, such as those highlighted above, but this approach negates both the uniqueness of the clinical context of smaller groups and acceptance that these groups are not directly comparable. Thus, in these circumstances, evidence-based practice may become reduced to a 'rule of thumb' in terms of clinical translation, with consequent reduced efficacy and patient-benefit. Bayesian approaches, in contrast, within the context of a comprehensive model of care, provide additional useful information that allows findings from large groups (patients with myocardial infarction for example) to be evaluated in smaller groups of cardiovascular patients with more exotic diagnoses to determine more realistically the transferability potential of established treatment approaches. Reflecting on the scope of information that may inform priors, and the known advantages of additional relevant information to improving treatment delivery and outcome, by definition such information sets the context for optimising intervention, care and outcomes within a complete bio-psycho-social model. Given that, in comparison to the dominant medical model, the bio-psycho-social model is more philosophically resonant with the dominant nursing models of practice, including those applied to cardiovascular nursing, the application of Bayes' theorem within cardiovascular nursing research facilitates a timely opportunity to foster and embed nurse-led cardiovascular research within this model and allow direct comparison with other approaches that are both measurable and replicable. The application of Bayes' theorem to cardiovascular nursing practice and research has been limited to date, however, the opportunities presented by application of the approach to the promotion and development of evidence-based practice to the field are long-overdue, and this approach could represent a dynamic and positive influence on outcomes for patients with cardiovascular disease and the professional esteem and scope of practice of nurses working within this specialty.

There is thus great potential to consider the application of a Bayesian approach to the many and varied clinical and research scenarios that face modern cardiovascular nurses. The main advantage of using Bayesian methods is to use significantly more information about a phenomenon, expressed in the form of a single probability distribution, in contrast to classical statistical methods which treat each study on the same theme independently, ignoring the existence of previous data. In cardiovascular nursing research, the application of Bayesian methods can, for instance, be useful for analysing the probability of diagnoses in specific groups, as well as analysing rare events, regardless of sample size. In addition, the Bayesian paradigm operates with the uncertainty concept, permitting its application in approaches that aim to determine factors such as accuracy, sensitivity and specificity. Thus, for example, this approach is a useful consideration for adoption by cardiovascular nursing research initiatives such as the Undertaking Nursing Research Throughout Europe (UNITE) study group.[21]

Despite these positive attributes, there are some limitations to the use of Bayesian analysis, including the need to know statistical distributions and calculus and to establish a prior distribution based on preliminary knowledge. Nevertheless, Bayesian methods are increasingly being used and offer great promise if applied judiciously to cardiovascular nursing research.

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