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A Review of: "*Clinical Prediction Models: A Practical Approach to Development, Validation, and Updating*, by E. W. Steyerberg"

David Ohlssen [a]
[a] Novartis Pharmaceuticals, East Hanover, New Jersey

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BOOK REVIEW

Clinical Prediction Models: A Practical Approach to Development, Validation, and Updating, by E. W. Steyerberg, New York: Springer, 2009, ISBN 978-0-387-77243-1, xxviii + 497 pp., $89.95.

When thinking about statistical developments in prognostic modeling, my thoughts immediately turn to the excellent work of Harrell (2001), who emphasized the need to use good statistical practice in all aspects of empirical modeling: for example, avoiding dichotomizing of continuous variables, using appropriate strategies to handle missing data, adopting modern estimation techniques that incorporate shrinkage, and the need for proper model validation using simulation-based techniques. Steyerberg, who cites Harrell's work as an important inspiration for his book, uses all of these ideas to form a principled strategy for the development of clinical prediction models. The introductory chapter presents an overview of this strategy, consisting of seven themes, which can be described as: (1) the definition of the prediction problem and research question; (2) the coding of the outcome of interest and predictors; (3) model specification; (4) estimation and inference; (5) examination of model performance in terms of model fit; (6) examination of predictive properties and dealing with overfitting; and (7) the presentation of results. While Harrell's earlier work also focused on developing a strategy, Steyerberg's book is aimed at a much more applied audience. The book is filled with many practical examples, and as possible statistical techniques are explained using text rather than mathematical notation, the material should be accessible to epidemiologists, public health researchers, and applied biostatisticians.

The remainder of the book is divided into four parts, the first of which (Chapters 2–6) considers motivating examples, an overview of study design, and a review of basic statistical modeling techniques that could be used in prediction modeling. The second part of the book (Chapters 7–18), focuses on providing a series of modern regression techniques, illustrated by various examples, which form the basis of the seven-part strategy. Part III (Chapters 19–21) examines generalizability or the external validity of prediction models. Finally, Chapters 22–24 consider a series of case studies.

The application areas and motivating examples described in Chapter 2 provide a good idea about the overall scope of problems that are addressed in the book. Examples include public health interventions in breast cancer; therapeutic decision making (replacement of risky heart valves); adjustment for covariates in randomized control trials; propensity score adjustment to examine the effect of statins on mortality rates; and the use of case-mix adjustment when comparing health care providers. Chapter 3 addresses design, rightly focusing on the need

to match the question of interest with appropriate levels of information. Some preliminary background on prediction modeling is provided in Chapters 4–6. Here basic modeling techniques such as (ordinal) logistic regression and Cox regression are described, as well as measures of predictability (R^2) and assessments of overfitting using bootstrapping. In general, classical regression techniques are emphasized, although other techniques such as classification trees and neural networks are reviewed. These introductory chapters appear to be well written and at an appropriate level for their intended audience.

The core part of the book is the second part, which aims to provide the tools, advice, and examples to allow implementation of the seven-part strategy. First, the issue of missing data (Chapters 7 and 8) is examined, with multiple imputation methods generally recommended. However, from the high-level description, the details of the approach were unclear to me. The challenge of coding predictors was discussed in Chapter 9. Here techniques that avoided the categorization of continuous predictors, such as restricted cubic splines and fractional polynomials, were recommended. More detail on the implementation of these techniques is provided in Chapter 12, which also considers nonlinearity and interaction terms.

The next topic considered is the selection of predictors, both at the design stage (Chapter 10) and during the subsequent modeling process (Chapter 11). In terms of design, focus is placed on the importance of subject knowledge and the need to match the number of predictors with the available data. The discussion of modeling initially centers around stepwise regression, which is still the most common approach used in the medical literature, but many of the potential drawbacks are highlighted. Modern alternatives such as model averaging, bootstrapping, and shrinkage are suggested. Later in the book, much more detail is provided on shrinkage methods (Chapter 13), including penalized maximum likelihood estimation and Lasso (least absolute shrinkage and selection operator).

The interesting idea of combining observational study data with external information, perhaps from a meta-analysis of relevant literature, is introduced in Chapter 14. The use of complex evidence synthesis has exploded over the past 5 years, but clearly it is only possible to scratch the surface in a single book chapter. The text focuses on a few simple techniques for bias correction when incorporating external evidence and some material on meta-analytic techniques. The final part of the core section examines model performance and presentation. Topics examined include classical measures of overall fit (Chapter 15), clinical utility (Chapter 16), internal assessment of predictability using simulation-based techniques (Chapter 17), and finally model presentation (Chapter 18). These topics are generally well presented and exemplified using the running case studies.

The final two parts of the book are much shorter sections that aim to support and further exemplify the seven-part strategy. The material in Part III follows directly from Part II, with a series of slightly more specialized topics, emphasizing the need for external model validity. In Chapter 19, the generalizability of case-mix adjustment is discussed in some detail, while Chapter 20 considers techniques for updating a prediction model in light of new data. Chapter 21 focuses on updating information on a series of objectives, using the example of hospital profiling. Part IV presents two complete case studies, with the aim of demonstrating the seven-part strategy in practice. The first looks at binary outcomes and the prediction

of a 30-day mortality rate after myocardial infarction using the GUSTO-I study. The second focuses on survival analysis using the SMART study.

Overall I think this is a well-written book that will have a wide appeal. The idea of defining a strategy to deal with clinical prediction problems might be somewhat controversial, but considering the variable quality of statistical analyses that appear in the medical literature, I believe such an approach is desirable. The book appears to have struck a good balance between practical examples and descriptions of statistical techniques. As with many recent books, statistical programs, in the R language, are made available, which allows the reader to implement many of the techniques described in the text. While technical or research-orientated biostatisticians might not find the style to their liking, it is refreshing to see a practical book applying many modern regression techniques to real problems.

REFERENCE

Harrell, F. E. (2001). *Regression Modeling Strategies: With Applications to Linear Models, Logistic Regression, and Survival Analysis*. New York: Springer.

David Ohlssen
Novartis Pharmaceuticals,
East Hanover, New Jersey