Bayesian Methods for the Estimation of Wound Closure and Area Change

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OPEN WOUND RESEARCH

The Purpose of This Work

- Formulate a Bayesian model to estimate wound closure and area change
- Illustrate the model by estimating the difference between groups in a Pretest-Posttest Group Design
- Deploy the Hurdle Gamma Distribution (HGD) (*Mullahy 1986; Heilbron 1994*)
- Use Bayesian ANCOVA with the HGD to estimate the parameters (α, β, ψ) of the HGD

Estimating Wound Closure and Area Change

- Wound data is a mixture of zeros and truncated long-tailed continuous data, a data generating process that the HGD addresses
- The zeros represent wounds that have closed, and the continuous data represents the wounds that have not closed
- Ψ (the probability of closure) can be estimated using a binomial regression, and the average wound area, given that a wound has not closed, can be modeled using α (mean), β (dispersion) of a Gamma regression.
- α, β, ψ will be estimated for both the the Standard-of-Care (SOC) group and Treatment Group, with a Bayesian ANCOVA using a HGD

Treatment Group	O_{pre}	X	O_{post}
Standard of Care (SOC)	O_{pre}		O_{post}

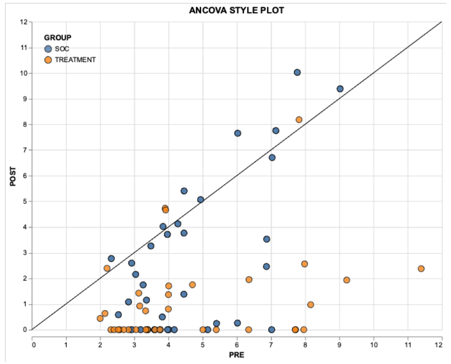
The Pretest-Posttest Control Group Design

Hurdle Gamma Model

$$
\begin{aligned}
y &\sim \text{Hurdle Gamma}(\alpha_{it}, \beta_{it}, \psi_t)\\
\text{logit}(\psi) &= \gamma_0 + \gamma_1 group_{it}\\
\log(\mu) &= \beta_0 + \beta_1 group_{it}\\
\gamma_0 &\sim \text{Normal}(0, 6)\\
\gamma_1 &\sim \text{Normal}(0, 6)\\
\beta_0 &\sim \text{Normal}(0, 5)\\
\beta_1 &\sim \text{Normal}(0, 5)\\
\psi_0 &\sim \text{Beta}(0, 1)\\
\psi_1 &\sim \text{Beta}(0, 1)
\end{aligned}
$$

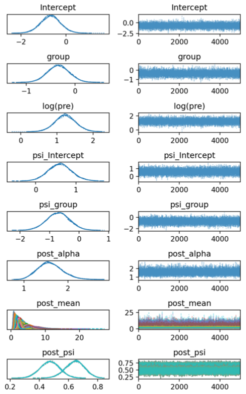
Simulate Small Sample Pretest-Posttest Wound Data

- Represents observational data collected
- 50 subjects with pressure ulcers of the heel in both the SOC and Treatment group
- The observation period was 12 weeks
- Then minimum size was $2 cm^2$ and the upper limit $12 cm^2$



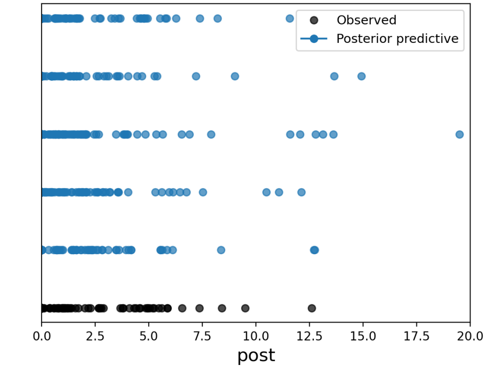
Markov Chain Monte Carlo Sampling

- Sample the posterior distribution with No U Turn Sampler (NUTS)



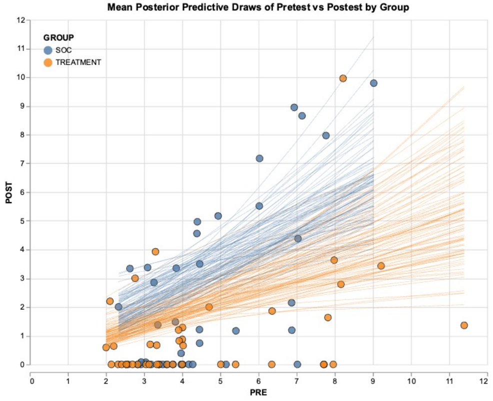
Posterior Predictive Check

- Generate full distribution of data from parameters of fitted model, the model simulated data should resemble observed data



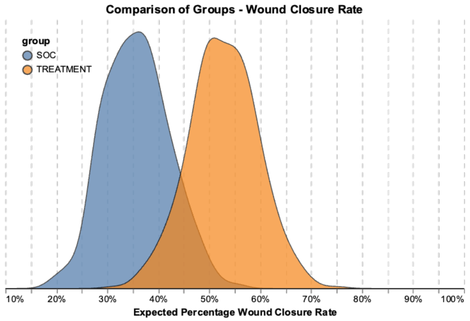
Generate Posterior Estimates Conditional on Original Data

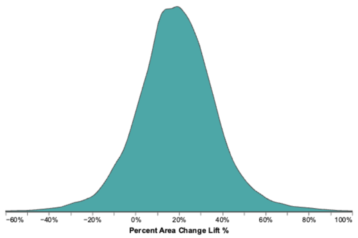
- Bayesian estimation allows full distribution of parameters of distribution and accounts for uncertainty

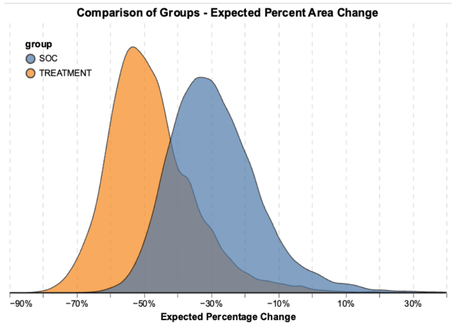


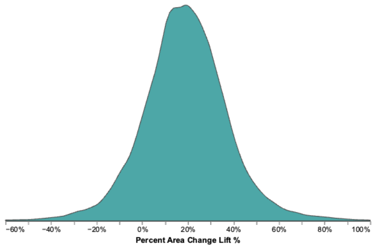
Generate Group Estimands and Comparisons

- Bayesian estimation allows full distribution of parameters of distribution and accounts for uncertainty. Posterior samples can easily be transformed to estimands.









The Model Can Generate Counterfactual Predictions

- Under the Bayesian regime it is straightforward to estimate unit and group level counterfactuals, e.g. what would have happened had the treatment group received the control and the control the treatment

Conclusion

- The Bayesian Hurdle Gamma ANCOVA is a powerful tool for the inference of the rate of wound closure, area change, and dispersion between groups
- Bayesian estimation accounts for uncertainty and allows for the incorporation of prior information including scientific knowledge and real-world constraints
- Bayesian estimation handles small N observational studies and large scale RCT's using the same model without the need for manifold adjustments
- All parameters and estimands provide full distributional information, allowing the researcher to ask answer questions naturally using the likelihood principle

References

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