H105 Mixed-Mode Assessment of Reference Lung Weights in a Medicolegal Autopsy Setting — A Bayesian Approach

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After attending this presentation, attendees will understand the relationship between postmortem lung weight and cause of death in a medicolegal autopsy setting.

This presentation will impact the forensic science community by providing new reference lung weights and the association between these reference weights and the cause of death.

Organs are routinely weighed at autopsy and, as such, present immediately accessible objective information that may be of importance for determining disease states and the cause of death.

Lungs are of particular interest as "heavy" lungs have been suggested as an autopsy finding associated with causes of death frequently encountered in a medicolegal autopsy setting, such as drowning and intoxication.[1-9] Problematic is the fact that "heavy lungs" have eluded a definition due to the high variability in lung weight.

Different reference weights have been suggested.[10-16] There have also been attempts at creating linear regression models using individual characteristics to estimate postmortem lung weight.[16] With the exception of one study, neither height, weight, age, nor Body Mass Index (BMI) have yielded R2 values of practical importance.[10] Previous studies were also generally limited by using selected and small populations.

A possible solution to this problem would be to model the lung weight as dependent on the cause of death. It is believed by some that this would be better suited for practical use, as it would appear that lung weight "as is" is far too variable to be of any use. Toward this end, this study attempted to create a varying intercepts regression model using groups based on underlying cause of death as intercepts and individual parameters as case-level predictors.

In Sweden, all medicolegal autopsies are performed at one of six departments of the Swedish National Board of Forensic Medicine. Organ weights and individual characteristics as well as the underlying cause of death are included in the medicolegal autopsy registry.

Using Stan®, interfaced through RStan, this study created multiple mixed-mode Bayesian general linear models using groups based on cause of death as varying intercepts and individual characteristics as case-level predictors.[17] Models were then compared for over- and underfitting, using the Widely Applicable Information Criterion (WAIC), after which a final "meta-model" based on individual model predictions weighted by their relative WAIC weight was created.[18,19]

Data from 2007 through 2013 was analyzed, including decedents 18 years or older but excluding cases with a postmortem interval longer than five days as well as cases with lacking, incorrectly registered, or extreme values. As the International Statistical Classification of Diseases and Related Health Problems (commonly known as the ICD) is ill-suited for a medicolegal autopsy population, groups were created based on the most common case types in our population. As this dataset is also very large, highly granular groupings could be created, allowing for instant subgrouping of different intoxicants in fatal intoxication cases. Results are presented using Highest Probability Density Intervals (HPDI).

This study found that group mean values exhibited a clear difference where expected, for instance between intoxication (mean 1303g (1,053–1,545g 95% HPDI)) and asphyxia (mean 1,029g (788–1,272g 95% HPDI)]; however, when accounting for individual case error rate, predictions were quite wide with significant overlap between case groups (e.g., intoxication (mean 1,303g (684–1,921 95% HPDI)) almost entirely overlaps asphyxia (mean 1,030g (411–1,647g 95% HDPI)).

It is believed this model still yields better, more realistic estimates for what constitutes normal lung weight in the estimated case groups, as these values represent probability distributions and values are less likely closer to the HPDI boundaries.

This reverse approach of assessing lung weight as a function of the cause of death also facilitates differential diagnostics as it provides the forensic pathologist with a better grasp of the context of a given lung weight in relation to one or more possible causes of death. In conclusion, this study submits these estimates are more realistic in forensic practice than previously published raw population means.

Reference(s):

1. Tomoko Sugimura et al. Application of the drowning index to actual drowning cases. *Legal Medicine*. 12: 68–72, 2010.
2. Zhu Bao Li et al. Postmortem lung weight in drownings: A comparison with acute asphyxiation and cardiac death. *Legal Medicine.* 5 :20–26, 2003.
3. Caroline Albion, Michael Shkrum, and James Cairns. Contributing factors to methadone-related deaths in Ontario. *The American Journal of Forensic Medicine and Pathology*. 31:313–319, 2010.
4. Charles V. Wetli, Joseph H. Davis, and Brian D. Blackbourne. Narcotic addiction in Dade County, Florida. An analysis of 100 consecutive autopsies. *Archives of Pathology*. 93:330–343, 1972.
5. Elisabeth E. Force, Russell S. Fisher and Jack W. Millar. Epidemiological and ecological study of risk factors for narcotics overdose. IV. Retrospective histopathological study of lungs in cases of fatal narcotism: Comparative analysis for potential hypersensitivity reaction. *Archives of Environmental Health*. 26 (1973): 111–19.

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6. Gary L. Henderson. Fentanyl-related deaths: Demographics, circumstances, and toxicology of 112 cases. *Journal of Forensic Sciences.* 36:422–33, 1991.
7. Steven B. Karch, Boyd Stephens, and Chih-Hsiang Ho. Relating cocaine blood concentrations to toxicity—An autopsy study of 99 cases. *Journal of Forensic Sciences.* 43:41–5, 1998.
8. Birgitte Kringsholm and Per Christoffersen. Lung and heart pathology in fatal drug addiction. A consecutive autopsy study. *Forensic Science International.* 34(1-2):39–51, 1987.
9. Jennifer L. Pilgrim, Michael McDonough, and Olaf H. Drummer. A review of methadone deaths between 2001 and 2005 in Victoria, Australia. *Forensic Science International.* 226:216–222, 2013.
10. Geoffroy Lorin De La Grandmaison, Isabelle Clairand, and Michel Durigon. Organ weight in 684 adult autopsies: New tables for a Caucasoid population. *Forensic Science International.* 119:149–154, 2001.
11. Jeffrey A. Hadley and David R. Fowler. Organ weight effects of drowning and asphyxiation on the lungs, liver, brain, heart, kidneys, and spleen. *Forensic Science International.* 133:190–196, 2003.
12. Rakesh Mandal, Agnes G. Loeffler, Shahriar Salamat, and Michael K. Fritsch. Organ weight changes associated with body mass index determined from a medical autopsy population. *The American Journal of Forensic Medicine and Pathology.* 33:1, 2012.
13. D. Kimberley Molina and Vincent J.M. DiMaio. Normal organ weights in men. *The American Journal of Forensic Medicine and Pathology.* 33:1, 2011.
14. D. Kimberley Molina and Vincent J.M. DiMaio. Normal organ weights in women Part II — The brain, lungs, liver, spleen, and kidneys. *The American Journal of Forensic Medicine and Pathology.* 36:182–187, 2015.
15. Ardeshir Sheikhazadi et al. Study of the normal internal organ weights in Tehran's population. *Journal of Forensic and Legal Medicine.* 17:78–83, 2010.
16. Torfinn Gustafsson, Anders Eriksson, and Carl Johan Wingren. Multivariate linear regression modelling of lung weight in 24,056 Swedish medico-legal autopsy cases. *Journal of Forensic and Legal Medicine.* 46:20–22, 2017.
17. Bob Carpenter et al. Stan: A probabilistic programming language. *Journal of Statistical Software.* 76, 2017.
18. Aki Vehtari, Andrew Gelman and Jonah Gabry. Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *arXiv*:1507.04544.
19. Watanabe, Sumio. Asymptotic equivalence of Bayes cross validation and widely applicable information criterion in singular learning theory. *Journal of Machine Learning Research.* 11 (2010): 3571–3594.

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