Actuarial projections for mesothelioma: an epidemiological perspective

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and Jill Shi
Who are we?

• I am an epidemiologist/biostatistician from the Australian National University (ANU)
• Geoffrey is an epidemiologist/biostatistician from the University of Sydney
• Jill is a trainee actuary from Mercer HR Consulting (actuarial honours from ANU)
Outline

• Background
• Theoretical model
• Model comparisons
• Discussion
Background

• Compensation for asbestos-related diseases continues to be an important issue for government and industry (Huszczo et al 2004)

• Focus on mesothelioma:
  – Cancer of the pleura and the peritoneum caused by asbestos exposure
  – Very important marker of exposure
Background: Challenges

• Poor measures of asbestos exposure
• Complexity in the epidemiological relationship between asbestos exposure and disease onset
• Uncertainty in the propensity to claim
• Uncertainty in future costs
Background: Aim

• Prediction of population-level mesothelioma incidence
  – Applicable to portfolios that follow population-wide asbestos exposure
  – We are not:
    • Predicting claims
    • Predicting costs
Background: Mesothelioma epidemiology

1. Incidence proportional to linear dose of asbestos exposure
2. Incidence depends on time from exposure
3. Incidence rises by a power of time from exposure
4. Evidence for asbestos clearance from the lungs
5. Several years between initial malignancy and diagnosis
6. Survival is poor and death is rapid.
Theoretical model: Notation for time, where $\mathbf{t} = (a, t) = (\text{age, calendar year})$

$u$: time since asbestos exposure
Theoretical model: Individuals

• For an individual $i$ exposed to asbestos at time $t-u$, the rate function is:

$$rate_i(a, t, u) = dose_i(a - u, t - u)g(u)$$

where

$$g(u) = \beta(u - \tau)^k e^{-\lambda(u-\tau)}$$

for constant $\beta$, lag $\tau$, power $k$ and lung clearance rate $\lambda$ (Armitage-Doll model with clearance).
Theoretical model: Populations

• The population rate is modelled by integrating (summing) across dose and times \( u \) since exposure:

\[
rate(a,t) = \int_{0}^{a} dose(a-u,t-u)g(u)du
\]
Theoretical model: Simplification

• Hodgson et al (2005):
  – Dose is proportional to an age effect $W()$ and a period effect $D()$
• That is (Equation 1):

$$rate(a,t) = \int_{0}^{a} W(a - u)D(t - u)g(u)du$$
Theoretical model: Cases

• The total numbers of cases for a year is:

\[ cases(t) = \int_{0}^{\infty} rate(a,t) \times Pop(a,t) \, da \]

• The number of cases is Poisson-distributed
Model comparisons: Data sources

- Mesothelioma incidence for males
  - Australia for 1983-2001
  - New South Wales for 1972-2004
## Model comparisons: Outline

<table>
<thead>
<tr>
<th>Model</th>
<th>Model description</th>
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<tbody>
<tr>
<td>Andrews and Atkins (1993)</td>
<td>cases(t) from Berry (1991)</td>
</tr>
<tr>
<td>Peto et al (1995)</td>
<td>Age-cohort model (sub-model of Equation 1)</td>
</tr>
<tr>
<td>KPMG</td>
<td>Exposure model with delay distribution (sub-model of Equation 1)</td>
</tr>
<tr>
<td>Clements et al (2007)</td>
<td>Equation 1</td>
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</tbody>
</table>
Mesothelioma incidence, calibrated Andrews and Atkins (1993), Australian males

![Graph showing observed and predicted mesothelioma incidence for Australian males from 1980 to 2060. The graph includes observed data before and after publication, as well as high and low predictions by Andrews and Atkins.](image-url)
Mesothelioma incidence, age-cohort model, Australian males

![Graph showing Mesothelioma incidence, age-cohort model, Australian males.](image-url)
KPMG (2006)

- Model as used to predict mesothelioma claims for former James Hardie entities
- Cases modelled by exposure data $D()$ and a delay distribution $f()$ (Normal($\mu=35$, $\sigma^2=10^2$)):
  $$cases(t) = \int_{0}^{\infty} D(t-u)f(u)du$$
- $D()$ based on consumption data:
  $$D(t) = \frac{\beta}{16} \int_{0}^{16} Consumption(t-u)du$$
Mesothelioma incidence, calibrated
KPMG, Australian males
Re-implementation of KPMG model

• Re-fit the model, estimating the intercept and the mean/SD for the delay distribution

• Maximum likelihood estimates:
  – Mean delay = 39.0 (se=5.0)
  – SD for delay = 10.4 (se=4.5)

• Interval estimation using the bootstrap
  – Assumes SD fixed as estimated (otherwise: uninformative)
Mesothelioma incidence, KPMG re-implementation, Australian males

![Graph showing mesothelioma incidence for Australian males from 1980 to 2060 with observed and predicted lines, along with 95% confidence intervals.](image-url)

• Hodgson et al (2005) modelled Equation 1 for the United Kingdom
• We re-implemented their model for NSW
  – Natural splines for the dose functions
  – Fitted for five parameters using maximum likelihood estimation
  – Interval estimation using the bootstrap
Mesothelioma incidence, Clements et al (2007), New South Wales males

![Graph showing observed and predicted mesothelioma incidence numbers with 95% confidence interval over the years 1980 to 2060.](image-url)
# Model comparison: Summary

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4 slides to go
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95% confidence interval: 16460, 30165

95% confidence interval: 4920, 9060

4 slides to go
Discussion: Summary

• Support for KPMG (2006), the KPMG re-implementation and Clements et al (2007)
  – Theoretically, these models are closely related

• Reasonable evidence that the peak for mesothelioma is after 2010
  – Total number of cases for 2006-2060 may be in excess of 35% higher than numbers predicted by KPMG
Specific recommendations

• Consider using the KPMG models or the model from Clements et al (2007)
• Investigate methods used by Stallard et al (2005) in the Manville Asbestos Case (also related to Equation 1) for large portfolios
• Investigate using direct estimates of asbestos exposure by occupation
General recommendations

• Fit models to observed data rather than simply calibrate
• Fully represent statistical uncertainty in model predictions
• The epidemiological literature is potentially a very useful resource to actuaries
References

Additional slides
Asbestos products available for consumption and a lagged exposure distribution, Australia
Estimated dose function by age, Clements et al (2007), NSW males
Estimated dose function by calendar period, Clements et al (2007), NSW males
Number of cases, by age at cancer, Clements et al (2007), NSW males
Number of cases, by period of exposure, Clements et al (2007), NSW males