Application of the Drowning Index to Opioid & Multidrug Intoxication Deaths: A Retrospective Analysis

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How common is drowning?

- Accidental drowning accounts for an average of 3,868 deaths per year (or approximately 10 deaths per day) in the United States, including drownings associated with boating incidents [1-2].

- In Missouri alone, accidental drownings have accounted for between 21 and 68 deaths per year since 2011; most of these have occurred in publicly-owned freshwater lakes and rivers during the summer months [3].

- The Office of Chief Medical Examiner of Boone & Callaway Counties names asphyxia due to drowning as the cause of death in an average of 11 cases each year (about 2% of our total cases).
Autopsy findings in drowning cases

- Marked pulmonary edema
  - Frothy or foamy fluid in airways
  - Increased lung weight
  - Dusky discoloration indicating vascular congestion
- Water in the stomach
- Hemorrhage of mastoid air cells in the middle ear
- Increased fluid volume in the maxillary sinus and sphenoid sinus ("Svechnikov’s sign")
- Presence of diatoms in pulmonary vasculature
- Hemolytic staining of the aortic intima (particularly in freshwater drownings)
- Decreased spleen weight [4-8]

The Drowning Index (D.I.)

Nishitani et al. (2006):

\[
\text{Drowning Index (DI)} = \frac{[\text{Lungs (g)} + \text{Pleural Effusion (g)}]}{\text{Spleen (g)}}
\]

The Drowning Index (D.I.)

Sugimura et al. (2010):

\[
\text{DI} = \frac{[\text{Lungs (g)} + \text{Pleural Effusion (g)}]}{\text{Spleen (g)}} \geq 14.1
\]

Specific for drowning vs. mechanical asphyxia and acute cardiac death
(A) shows foamy secretions in the trachea; (B) and (C) show foam in the bronchi (pulmonary edema) and dusky discoloration of the lung parenchyma indicating significant congestion.

Figure 1. Photos from Drowning

Figure 2. Photo from Opioid Intoxication

Foamy secretions in the trachea

Can you tell the difference?
Case Selection

- Causes of death from Boone-Callaway County Medical Examiner’s Office in Columbia, Missouri cases between January 1, 2011 and December 31, 2016 were collected.
- Deaths due to drowning, opioid intoxication, multidrug intoxication, and asphyxia due to hanging were identified.
- Cases were excluded if:
  - They contained insufficient data for analysis.
  - The body showed signs of decomposition at time of autopsy.
  - The decedent was under the age of 18 years.
- Cases were not separated for analysis based on gender or age.

Data Collection

- 536 total cases were identified:
  - 45 drowning cases
  - 180 opioid intoxication cases
  - 261 multidrug intoxication cases
  - 50 hanging cases
- The body weight, spleen weight, bilateral pleural effusion volumes, and bilateral lung weights for each case were recorded.
  - Pleural effusion volume for each autopsy is estimated in milliliters.
  - If no pleural effusion volume was recorded, the minimum pleural fluid volume was estimated using 0.16 milliliters/kilogram body weight [14].
  - Pleural effusion volumes were converted to weight in grams using a density of 1 gram/milliliter.

Calculations

- The DI was calculated for each case [9].
- The DI, combined effusion and lung weight, and spleen weight was compared among the cause of death groups.
  - The Mann-Whitney U-test was used to evaluate for statistical significance using a 95% confidence interval (p < 0.05).
Table 1. Summary of Data from Each Cause of Death Group

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Drowning (grams)</th>
<th>Opioid Overdose (grams)</th>
<th>Multidrug Intoxication (grams)</th>
<th>Asphyxia due to Hanging (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
<td>45</td>
<td>185</td>
<td>261</td>
<td>51</td>
</tr>
<tr>
<td>Effusion + Lungs</td>
<td>1663 (995-2790)</td>
<td>1562 (664-3530)</td>
<td>1409 (576-4050)</td>
<td>1268 (467-2010)</td>
</tr>
<tr>
<td>Spleen</td>
<td>100 (35-580)</td>
<td>355 (261-660)</td>
<td>320 (164-550)</td>
<td>200 (15-500)</td>
</tr>
<tr>
<td>Weight</td>
<td>7.9 (3.0-25.2)</td>
<td>5.6 (1.1-30.5)</td>
<td>4.2 (1.0-33.0)</td>
<td>6.4 (2.1-31.5)</td>
</tr>
</tbody>
</table>

*Data are given as median (minimum-maximum)
Figure 3. Comparison of DI among Cause of Death Groups

Table 2. Percentage of Cases with DI > 14.1

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drowning</td>
<td>13.3% (6/45)</td>
</tr>
<tr>
<td>Opioid Intoxication</td>
<td>6.1% (11/180)</td>
</tr>
<tr>
<td>Multidrug Intoxication</td>
<td>3.5% (9/261)</td>
</tr>
<tr>
<td>Asphyxia due to Hanging</td>
<td>0.0% (0/30)</td>
</tr>
</tbody>
</table>

Drowning Index (D.I.)

- The lowest DI (1.1) was associated with an opioid overdose and highest DI (33) was associated with a multidrug overdose.
- Drowning cases accounted for the highest mean DI of the causes of death studied.
- DI > 14.1:
  - 6 of 45 drowning cases (13.3%) 
  - 11 of 180 opioid overdoses (6.11%) 
  - 9 of 261 multidrug overdoses (3.45%) 
  - 0 of the hangings (0%) 
- The specificity of the DI for drowning is 95%.
- The sensitivity of the DI for drowning is 13%.
Discussion

- Combined lung and pleural effusion weight are meaningless when distinguishing between drowning, acute opioid intoxication, and acute multidrug intoxication deaths.
- The inclusion of spleen weight confers a higher specificity of the DI when compared to combined lung and effusion weight alone.
- A DI greater than or equal to 14.1 cannot be considered diagnostic of drowning.
- The drowning index has no applicability in distinguishing between asphyxia or “asphyxia-like” deaths, including those associated with acute drug intoxication.

Areas for Further Research

- Future research to investigate the possibility of decreased spleen weight in true asphyxial deaths, such as drowning and hanging, is warranted.

References