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Life Expectancy After Catastrophic Injury

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Outline of Today’s Talk

• Basic ideas related to life expectancy (terminology, the life table, mortality rates)
• The scientific approach to life expectancy
• Life expectancy in the general population (GP)
• Life expectancy in three catastrophic conditions: cerebral palsy (CP), traumatic brain injury (TBI), and spinal cord injury (SCI)

Basic Ideas Related to Life Expectancy

• The biggest point: Survival time can’t be predicted.
• Two summary measures of survival time
  – Median survival time = 50% mark
  – Life expectancy = average (arithmetic mean) survival time
• A simple example: 1, 2, 9
  – Median = 2
  – Life expectancy = (1+2+9)/3 = 4
Example 1: 70 Year-Old U.S. Males

Example 2: Insured 70 Year-Old Males
Survival curves for persons like the 10-year-old male plaintiff (blue line) and for the U.S. male general population (red line).
2009 U.S. Life Table For Males

<table>
<thead>
<tr>
<th>age</th>
<th>l(x)</th>
<th>d(x)</th>
<th>m(x)</th>
<th>L(x)</th>
<th>T(x)</th>
<th>e(x)</th>
</tr>
</thead>
<tbody>
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<td>2867</td>
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<td>997</td>
<td>376</td>
<td>0.4736</td>
<td>809</td>
<td>2144</td>
<td>2.2</td>
</tr>
</tbody>
</table>

The Life Table

- Constructed using standard actuarial methods
- Not as complicated as it may first seem
- What goes in? The mortality rates, m, at every age, x, denoted m(x)
- What comes out? Everything else, including
  - The life expectancy at age x, e(x)
  - The number of people alive at age x, l(x), out of 100,000 alive at the starting age. Converting to a percentage, this is just the survival curve.
Factors That Affect Life Expectancy

• Positive
  — Race: Hispanic
  — Education: College
  — Lifestyle: Non-smoker, regular exercise, ideal weight, and moderate alcohol
  — Religion: Mormons and Seventh Day Adventists

• Negative
  — Lifestyle: Smoking, sedentary, and obesity
  — Diseases and medical conditions
  — Birth and acquired injuries

2009 U.S. Life Expectancy

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>76</td>
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<td>90</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: National Center for Health Statistics
National Vital Statistics Reports, Volume 62, Number 7
The Scientific Approach To Life Expectancy

- Identify the factors that are relevant
  - Demographics, Lifestyle, Medical conditions
  - For the disabled: Mobility, feeding, epilepsy, cognitive abilities, respiratory and other health issues, scoliosis, contractures, asthma

- Use the available scientific evidence, either
  - The medical literature, or
  - A large survival data base of similar persons

- Lastly, consider any factors that could not be explicitly quantified: "plusses and minuses"
Spinal Cord Injury (SCI)

- 10,000 injuries per year
- 200,000 persons currently alive with SCI
- 82% of injuries are to males
- Causes: MVA, violence, falls and sports
- Cost of care
  - 1st year: $150,000 to $500,000
  - Thereafter: $10,000 to $100,000

Morbidity in SCI

- Deep vein thrombosis
- Pulmonary embolism
- Pressure sores
- Urinary tract infections, and upper urinary tract dilation (overfilling, which can trigger autonomic dysreflexia - potentially life-threatening)
- Urinary calculi (from demineralization of bones due to immobility)
- Contracture of muscles, which can lead to fixed deformities
- Limitations of range of motion in the paralyzed joints
- Constipation and hemorrhoids
- Osteoporosis and fractures of the long bones
- Syringomyelia (a progressive disease of the spinal cord, which in the case of a cervical injury could further damage the respiratory system)
Mortality in SCI

- Cardiovascular
- Respiratory (pneumonia and influenza)
- Suicide and other accidents
- Septicemia
- Pulmonary embolism


Determinants of Life Expectancy in SCI

- Age and sex
- Neurologic level of injury. Example: C3
- Severity of injury: Complete (ASIA grade A) or incomplete paralysis (BC); i.e., with or without sensation
- Ventilator dependence
- Time since injury
- Minor factors (race, etiology, sex)
Life Expectancy After SCI (crude)

Male, Age 25

C1-C4 ABC (High Quadriplegia) 30
C5-C8 ABC (Low Quadriplegia) 35
T1-S5 (Paraplegia) 41
ASIA Grade D 45

U.S. General Population 52

### Life Expectancy After SCI (detailed)

#### Table 4: Sample Life Expectancies for 25-Year-Old White Man: Nonviolent Etiology and Time Since Injury 3 Years, by Injury Level and ASIA Grade

<table>
<thead>
<tr>
<th>Group</th>
<th>Life Expectancy (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General population</td>
<td>50.9</td>
</tr>
<tr>
<td>C1, grade A</td>
<td>25.4</td>
</tr>
<tr>
<td>C1, grades B and C</td>
<td>32.2</td>
</tr>
<tr>
<td>C4, grade A</td>
<td>26.4</td>
</tr>
<tr>
<td>C4, grades B and C</td>
<td>34.9</td>
</tr>
<tr>
<td>C5, grade A</td>
<td>30.0</td>
</tr>
<tr>
<td>C5, grades B and C</td>
<td>35.7</td>
</tr>
<tr>
<td>C6, grade A</td>
<td>34.7</td>
</tr>
<tr>
<td>C6, grades B and C</td>
<td>36.7</td>
</tr>
<tr>
<td>T1-S5 (paraplegia), grades A, B, and C</td>
<td>37.6</td>
</tr>
<tr>
<td>All grade D</td>
<td>44.7</td>
</tr>
</tbody>
</table>

Source: Strauss et al. (2006).

### Life Expectancy After SCI (AIS D)

#### TABLE 4 Life expectancies for AIS Grade D SCI, stratified by age, sex, and functional group a

<table>
<thead>
<tr>
<th>Age</th>
<th>Paraplegia, AIS A, B, C</th>
<th>Wheelchair Dependent</th>
<th>Wheelchair Independent</th>
<th>Walks with Assistive Device</th>
<th>Walks Independent</th>
<th>GP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All AIS D</td>
<td>No Catheter</td>
<td>Indwelling</td>
<td>No Catheter</td>
<td>Indwelling</td>
<td>No Catheter</td>
</tr>
<tr>
<td>Men</td>
<td></td>
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<td></td>
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<td>6</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

a All of the results given here are based on the assumption of no improvement or decline in function, even in older age. That is, the life expectancy applies to someone who is assumed to remain in the stated group for the remainder of his/her life. This assumption may be overly optimistic for the higher functioning groups and lead to some overestimation of life expectancy.

b These values were derived using the model given in Table 3 of Strauss et al. and are provided for comparison.

c The combined group of all persons with AIS D, as shown in Table 2 ("Simple Model IV"), based on mortality rates from the logistic regression survival model with terms only for age (a linear term) and sex.

d Use wheelchair as primary means of locomotion; cannot operate independently; requires assistance or supervision.

e Uses wheelchair as primary means of locomotion; operates independently; no supervision required.

f Walks without the assistance or supervision of another but requires brace, special shoes, cane, or crutch.

These values were derived using the model given in Table 3 of Strauss et al. and are provided for comparison.

Source: Shavelle (2014).
How to Rate Co-Morbid Factors

• Suppose the person has factor x, which usually has a rating of +50 (MR=rr=1.5) [Note: Of course the rating could depend on the baseline condition.]
• How to account for factor x?
  • If all persons with SCI have x, then no adjustment is necessary
  • If none have it, full adjustment

How to Rate Co-Morbid Factors (continued)

• Let p = proportion who have it
• Let r = relative risk of mortality for those who have it compared with those who do not
• Then the proper adjustment factor (adjusted relative risk) is:
  \[ f = \frac{r}{pr + (1-p)} \]
• Check: If p = 0, r = r and if p = 1, f = 1
Recent SCI Literature


Traumatic Brain Injury (TBI)

• 1.5 million injuries per year at cost of $25 billion to society
• 50,000 deaths per year
• 230,000 are hospitalized and survive
• 85,000 experience long-term disability
• Etiology: MVA, violence, and falls
Morbidity/Mortality in TBI

- Seizures
- Respiratory infections
- Choking and other accidents
- Cardiovascular disease


Conditions Caused by TBI?

<table>
<thead>
<tr>
<th>Condition</th>
<th>References</th>
</tr>
</thead>
</table>
Determinants of Life Expectancy in TBI

- Age
- Sex
- Motor function
- Tube feeding or other feeding ability
- Time since injury (the first few years)
- Epilepsy
- Cognitive function

Life Expectancy After TBI: Males

<table>
<thead>
<tr>
<th>Age</th>
<th>PVS</th>
<th>Cannot Walk</th>
<th>Some Walking Ability</th>
<th>Walks Well Alone</th>
<th>GP</th>
</tr>
</thead>
<tbody>
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<td>7</td>
<td>11</td>
<td>19</td>
<td>20</td>
<td>23</td>
</tr>
</tbody>
</table>

\(a\) Persistent vegetative state. Tube fed.
\(b\) Fed by others, either orally or by a feeding tube.
\(c\) Self feeds with fingers or utensils.
\(d\) General population.

Source: Table 17-3 of Shavelle et al. (2007).
Life Expectancy After TBI: Females

<table>
<thead>
<tr>
<th>Age</th>
<th>PVS(\text{a})</th>
<th>FBO(\text{b})</th>
<th>SF(\text{c})</th>
<th>Some Walking Ability</th>
<th>Well Alone</th>
<th>GP(\text{d})</th>
</tr>
</thead>
<tbody>
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<td>11</td>
<td>26</td>
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<td>23</td>
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<td>32</td>
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</tbody>
</table>

\(\text{a}\) Persistent vegetative state. Tube fed.  
\(\text{b}\) Fed by others, either orally or by a feeding tube.  
\(\text{c}\) Self feeds with fingers or utensils.  
\(\text{d}\) General population.

Source: Table 17-2 of Shavelle et al. (2007).

Recent TBI Literature

Cerebral Palsy (CP)

- A term of convenience to describe motor disorders due to brain impairment
- Affects roughly 1 in 500 live births
- Non-progressive; appears early in life
- Possible causes include hypoxia before or during delivery, head trauma, and infections.
- The exact cause in most cases cannot be determined.
- Effects range from very mild to very severe

Morbidity/Mortality in CP

- Respiratory diseases, especially in the young
- Spasticity, contractures, scoliosis, asthma
- GERD, UTI, accidents
- Heart disease and other effects of immobility

Complications Of Immobility

- **Cardiovascular**: Decreased cardiac output, contributing to decreased aerobic capacity; orthostatic intolerance; venous thrombophlebitis
- **Pulmonary**: Atelectasis; relative hypoxemia; pneumonia
- **Musculoskeletal**: Muscle atrophy and loss of strength; decreased muscle oxidative capacity contributing to decreased aerobic capacity; osteoporosis (bone loss); contractures; osteoarthritis
- **Gastrointestinal**: Constipation
- **Genitourinary**: Incontinence; renal calculi and urinary tract infections
- **Skin**: Pressure ulcers due to tissue ischemia
- **Functional**: Impaired ambulation and activity intolerance
- **Psychological**: Depression; altered sensory perception


Determinants of Life Expectancy in CP

- **Many potential factors**
  - Etiology
  - Type of CP
  - Severity of MR (mental retardation level)
  - Ethnicity, Socioeconomic status
  - Type of residence
  - Many don’t matter (e.g., hair color)

- **The biggest factors**
  - Motor function: rolling, sitting, crawling, walking
  - Feeding: gastrostomy tube, FBO, self feeds
The Normal Developmental Sequence

• Lifts head (at age 0-1 month)
• Lifts head and chest (2-4 months)
• Rolls (3-7 months)
• Sits (5-9 months)
• Crawls (6-12 months)
• Stands (7-13 months)
• Cruises, walks with support, then walks alone (8-17 months)

Two Other Factors

• Quality of care: "With good care normal life expectancy".
  – True for a normal child. Not true for the disabled.
  – Does care matter? If "good" versus "bad", then yes. If "excellent" versus "reasonable & necessary", then no.
• Secular (time) trend:
  – "Those old historical studies do not apply in today’s age of modern medicine!"
  – Evidence of a trend in the past 20 years!
Life Expectancy in CP: 4 Year-Old Male

- Persistent Vegetative State (PVS), Tube Fed (TF) 14
- Immobile Minimally Conscious State (IMCS), TF 15
- Unable to lift head, tube fed by gastrostomy 18
- Able to lift head, tube fed by gastrostomy 21
- Able to lift head, fed by others 28
- Able to lift head, can self feed 48
- Very high functioning (can walk and self feed) 68

- U.S. General Population - Males 73

Source: Derived from the survival figures given in Table II of Brooks et al. (2014).

Recent CP Literature

Amusing Statements About Life Expectancy By Clinicians

• His life expectancy at the time of the accident, 3 years ago, was 10 years, so it’s now 10 - 3 = 7 years
• With optimal medical care, the life expectancy [of this person in the vegetative state] is near normal
• He could die any day, so his life expectancy could be very short
• Very few of my patients have died, so with good care I believe his life expectancy will be normal
• This man is 20, but will likely make it to age 50, when the life expectancy is 30 years, so his life expectancy is to age 80
• Most of my patients are in their 40’s, 50’s or 60’s, so I think this man’s life expectancy is to the middle of this range -- his 50’s

Summary

• Life expectancy is not a prediction of the person’s actual survival time.
• Life expectancy in cerebral palsy, traumatic brain injury, and spinal cord injury varies according to the severity of disability.
• A large body of medical literature can be used to estimate life expectancy.