SURVIVAL ESTIMATION: THE KAPLAN–MEIER METHOD APPLIED IN ENDOPROSTHETICS

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Abstract:
The paper Survival Estimation: the Kaplan–Meier Method Applied in Endoprosthetics aims to answer a particular research question regarding the estimation of the survival period for patients benefiting from the National Public Health Program conducted by the Ministry of Health. The research method used is the Kaplan–Meier survival estimator. This method allows the estimation of the survival period following prosthetic interventions.

Key words: *Kaplan–Meier Method, endoprosthetics, survival*

JEL classification: *C02, C40, C60*

1. Introduction:

An important goal for every physician is to prevent and cure patients. Most health professionals are interested in studying the survival period from the hospital admission date until the final moment, death or full recovery.

The purpose of a survival analysis by means of the Kaplan-Meier method is to model and analyze the length of time until the occurrence of the next event. An event is not defined as death, but it may include other positive or negative events.

The research question that arises in the case of endoprosthetics operations is: What is the probability for a male or female patient of a certain age, to stay alive over a period of 1 or 3 years following an endoprosthetics operation? The answer is detailed in several stages of the research. During the first stage, the database necessary for the survival probability analysis in the case of an endoprosthetics intervention was built. This database contains records of hospital admission, gender, age of the patient, subsequent events and, as appropriate, the survival period expressed in months.

2. Mathematical model of the survival curve

The first and simplest approach to estimate the survival curve belongs to Böhmer (1912). Later, in the 1950s, Paul Meier and Edward Kaplan [2], [3] rediscovered and defined the concepts of survival estimation.

Thus, if an event is recorded for every date $t_i,$, then the number $\mathrm{n}(t_i),$ of patients at risk is recorded (if there is no censoring in the data). Afterwards, the probability for a patient at risk to go through another event during the time $k_i,$ is estimated; this probability is calculated using the formula:

$$\mathrm{P}(\text{survive danger time } t_i,) \approx \frac{\mathrm{n}(t_i) - 1}{\mathrm{n}(t_i)}$$

The Kaplan-Meier survival estimation method involves determining the probability $\tilde{\text{E}}(t)$ for each patient at risk.

Let us consider $k_i,\ cu\ i = \overline{1,m}$ a set of separate events $\text{K} = \max_{i=\overline{1,m}} k_i$, occurring over a certain period, $t_1 < t_2 < \cdots .. < t_k$. For each t_i, there are $p_i,\ i = \overline{1,m}$ risk periods, and a number of patients with risk events at the time $t_i\ \ cu\ i = \overline{1,m}$ noted by q_i .

The Kaplan-Meier survival estimator $\text{E}(\text{k})$ depending on k is defined by formula:

$$\tilde{\text{E}}(k) = \prod_{i,k_i \le k} \frac{(q_i - p_i)}{q_i} \quad pentru\ \ k \epsilon [o, K]$$

3. Standard error in case of the survival curve $\tilde{\text{E}}(k)$:

1. Greenwood's formula is

$$Var\ \tilde{\text{E}}(k) = [\tilde{\text{E}}(k)]^2 \sum_{i,k_i \le k} \frac{p_i}{[q_i(q_i - p_i)]}$$

2. Tsiatis' formula is [4]

$$Var\ \tilde{\text{E}}(k) = [\tilde{\text{E}}(k)]^2 \sum_{i,k_i \le k} \frac{p_i}{{q_i}^2}$$

4. Trust intervals:

- $\tilde{\text{E}}(k) \pm 1.96 \sqrt{Var\ \tilde{\text{E}}(k)}$
- The natural logarithm is estimated and retransformed. The inverse of the logarithm function is the exponential function ($ln^{-1} = exp$).
- We calculate $\ln(-\ln)$, and we transform $y \to \ln(-\ln(y))$ with the inverse of the function $y \to e^{-e^y}$, and then, we transform again the formula. It is satisfying for limited intervals, with 25-50% censoring and respecting the limit $\text{E}(\text{k}) \in [0,1]$.

Conclusions

The Kaplan-Meier method is widely used in analysing the patients' survival. This method provides a mathematical estimation using important concepts of probability and a clear graphical representation of the survival curve with censored or uncensored elements.

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