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Estimating the Survival Function of HIV/AIDS Patients using Weibull Model

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ABSTRACT

This work provides information on the survival times of a cohort of infected individuals.

The mean survival time was obtained as 22.579 months from the resultant estimate of the shape parameter γ=1.156 and scale parameter λ=0.0256 from Weibull 7++ simulation of n = 500. Confidence intervals were also obtained for the two parameters at ∝= 0.05 and it was found that the estimates are highly reliable.

KEYWORDS: *Cohort, Survival time, Shape parameter, Scale parameter, Weibull7++, Simulation, Confidence intervals*

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INTRODUCTION

Survival analysis deals with the methods of measuring the risk of death or sequence of an event or a disease which provides predictions that help clinicians in estimating the patterns in their patient outcomes. These methods also serve as guide for health planners in predicting the effects of HIV on the health system and for proper allocation of health services and resources.

Survival times vary according to a number of some parameters which includes; socio-demographic factors, CD4 cell counts, HIV viral load and AIDS-defining illnesses. These covariates are considered in the models allowing predictions of their effects on the time to development of AIDS and to death. Cox regression, a semi-parametric model, has been widely used for this, because lesser assumptions are required for prediction of the prognostic factors associated with survival. However, studies have shown that parametric models are known to be more precise than non-parametric methods when using survival models to make prodictions about the risk of death [1,2] and future trends in mortality [3]. Concurrently, with development of survival models based on HIV and AIDS data, researchers such as in [4,5,6,7,8,9] have attempted the usage of parametric models and studied the validity of parametric models. Therefore, in this study, the survival function of Patients with HIV/AIDS will be estimated using the Weibull distribution.

MATERIALS AND METHODS

The Weilbull probability distribution of survival times is defined by two parameters; λ (scale parameter) and γ (shape parameter). The two parameters provide additional flexibility that potentially increases the accuracy of the description of a survival data. The shape parameter allows the hazard function to increase or decrease with increasing time. The Weibulls survival probability function is obtained as follows

$$S(t) = P(T \geq t)\ t > 0$$
$$= \int_t^{\infty} \lambda\gamma t^{\gamma-1} e^{-\lambda t^{\gamma}} dt$$
$$= e^{-\lambda t^{\hat{a}}} \quad (1)$$

RESULTS

A survival data of n = 500 was used using Weibull7++ simulation software and the generated maximum likelihood estimates of the parameters and their associated variances were obtained.

The maximum likelihood estimates of the parameter are:
$\hat{\lambda}$ = 0.0256 and $V(\hat{\lambda})$ = 0.000044;
$\hat{\gamma}$ = 1.156 with $V(\hat{\gamma})$ = 0.00519

The associated variance of the log estimate of λ is given as
$$Var\ (\log(\hat{\lambda})) = \frac{1}{\hat{\lambda}^2} Var(\hat{\lambda}) \quad (2)$$
and the variance of the log estimate of $\hat{\gamma}$ as
$$Var\ (\log(\hat{\gamma})) = \frac{1}{\hat{\gamma}^2} Var(\hat{\gamma}) \quad (3)$$

An approximate 95% confidence interval based on the normal distribution and the transformed log-estimates is

$$\log(estimate) \pm Z_{\frac{\alpha}{2}}\sqrt{V[log(estimate)]} \quad (4)$$

Hence the estimated survival times is given by

$$\hat{S}(t) = e^{-0.0256t^{1.156}}$$

The confidence interval based on each of the estimated Weibull parameters are more accurately constructed in logarithmic transformation

A log-transformation yields $\log(\hat{\lambda}) = -3.662$ and

$Var(\log(\hat{\lambda})) = \frac{1}{\hat{\lambda}^2} Var(\hat{\lambda}) = 0.066$

$\log(\hat{\gamma}) = 0.0145$ with estimated variance

$Var(\log(\hat{\gamma})) = \frac{1}{\hat{\gamma}^2} Var(\hat{\gamma}) = 0.0039$

An approximate 95% confidence interval based on the normal distribution and the transformed log-estimates is

$\log(estimate) \pm Z_{\frac{\alpha}{2}}\sqrt{V[log(estimate)]}$

with $\alpha = 5\%$, $\frac{\alpha}{2} = 1.960$

The log-transformation improves the normal distribution approximation by creating more symmetric distribution for

$\log(\hat{\lambda})$, the 95% confidence interval is

$-3.662 \pm 1.960\sqrt{0.66} = (-4.167, -3.157)$ and for

$\log(\hat{\gamma})$, the 95% confidence interval is

$0.145 \pm 1.960\sqrt{0.0039} = (0.023, 0.267)$

Exponentiating these estimated bounds yields approximate confidence intervals for the parameters as scale parameter:

$\hat{\lambda} = 0.0256$ and the 95% confidence interval is (0.016, 0.043)

$\hat{\alpha} = 1.156$ giving the 95% confidence interval as (1.023, 1.306)

The estimated mean survival time, based on the Weibull distribution is

$$\hat{\imath} = \hat{e}^{-\left(\frac{1}{\hat{a}}\right)}\Gamma(1+\tfrac{1}{\hat{a}})$$
$$= 0.0256^{-1/1.156}(0.950)$$
$$= 22.597\ months$$

CONLUSION

The average survival time for a cohort of infected individuals is 22.60 months approximately. This implies that an individual who is diagnosed of HIV/AIDS will live for approximately 22.60 months before his/her death provided that no anti-retroviral drug is applied.

The confidence interval obtained using the normal distribution with $\acute{a} = 0.05$ reveals that the estimated parameters face with their repective confidence limits. Hence the use of Weibull distribution for estimating the survival function of Patient with HIV/AIDS is precise and reliable.

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