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Estimation of Premium Cost for HIV/AIDS Patients Under ART in Presence of Prognostic Factors

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Abstract

This paper focuses to introduce an insurance plan for HIV/AIDS patients by incorporating the prognostic factors. High death rate among the HIV infected people always made a poor attention towards the insurance companies. The use of ART has declined the death rates drastically over the years which show a clear path for sustainable insurance plan. The long term survivors among HIV/AIDS patients can be treated as any other patient. The diagnosis involves a lot of time and financial investment. An affordable insurance plan will support the next of kin in case of patient's death. The survival probabilities in the presence of prognostic factors are obtained using COX-PH model and hence the cost of the premium is obtained using actuarial model.

Key words: HIV/AIDS; CD4; COX-PH; Regression; Premium; ART.

1. Introduction

Globally, there are 37.7 million people living with HIV/AIDS and 2.3 million in India in 2020. The incidence rate per 1000 uninfected population is 0.19 and 0.04, globally and India respectively. 6.8 million people died from HIV/AIDS-related illnesses in 2020 UNAIDS (2021),NACO (2019). The human immunodeficiency virus (HIV) targets the immune system and weakens people's defense against many infections and some types of cancer that people with healthy immune systems can fight off. As the virus destroys and impairs the function of immune cells, infected individuals gradually become immunodeficient. Immune function is typically measured by CD4 cell count and viral load. The most advanced stage of HIV infection is acquired immunodeficiency syndrome (AIDS), which can take many years to develop if not treated, depending upon the initial health of the individual. As per WHO, the stages of HIV/AIDS on the basis of CD4 count, WHO (2005) are presented in Table 1.

HIV can be managed by treatment regimens composed of a combination of three or more antiretroviral (ARV) drugs. Current antiretroviral therapy (ART) does not cure HIV infection but highly suppresses viral replication within a person's body and allows

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Table 1: Clinical staging of HIV/AIDS infection established by WHO

Symptoms	Clinical stage	CD4 per microlitre
Asymptomatic	1	≥ 500
Mild symptoms	2	350-499
Advanced symptoms	3	200-349
Severe symptoms	4	< 200

an individual's immune system recovery to strengthen and regain the capacity to fight off opportunistic infections and some cancers.

Since 2016, WHO has recommended that all people living with HIV be provided with lifelong ART, including children, adolescents, adults and pregnant and breastfeeding women, regardless of clinical status or CD4 cell count WHO (2016). Around the world, 27.5 million people were able to access antiretroviral therapy (ART) in 2020 and 1.5 million in India UNAIDS (2021).

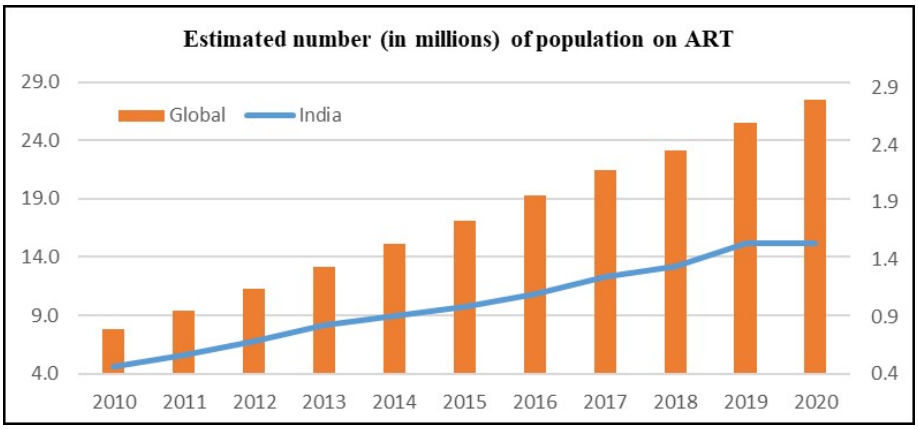

Figure 1: Estimated number (in millions) of population on ART, UNAIDS 2021

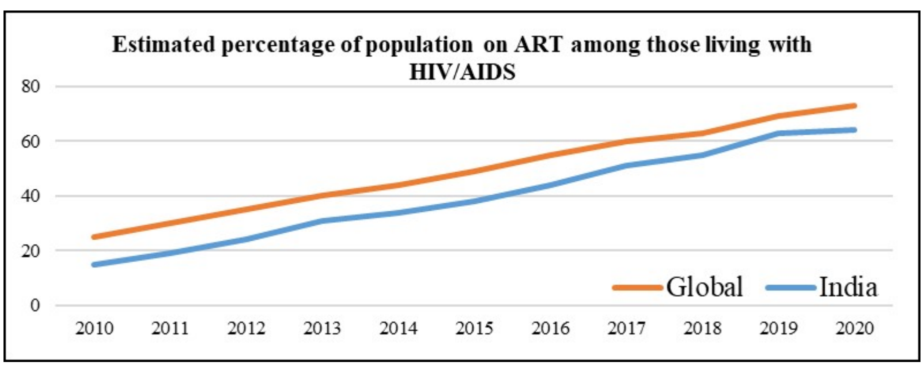

Figure 2: Estimated percentage of population on ART among those living with HIV/AIDS, UNAIDS 2021

Figure 1 shows the estimated population receiving ART globally and in India. The overall trend is upwards. Also, out of the infected population there is steady increase in access to ART, Figure 2. The worldwide increased use of ART has contributed crucially for decline in rate of death, Collaborators *et al.* (2016), NACO and ICMR-NIMS (2017). This decrease in deaths shows long term survival in HIV/AIDS patients King Jr *et al.* (2003).

HIV/AIDS patients face a lot of problems in their day to day life. One such big problem is financial instability. The detection and treatment process exhausts a lot of time and money. The cost per new HIV diagnosis involves Rs. 866 to Rs. 1367 in England, Ong *et al.* (2016) and Rs. 1200 to Rs. 1610 in USA, Burns *et al.* (2013). According to NSSO 71st round data the average cost of diagnosis for the same is Rs. 1336 in India, Jain *et al.* (2015). Generally, the cost of diagnosis and other medical expenses are borne by the insurance company but there is no such provision for HIV/AIDS patients. This is due to high death rate in the infected population and expensive diagnosis. The current scenario of HIV/AIDS patients promises long term survival which supports the idea of providing an insurance plan for them.

Insurance is a means of protection from financial loss. It is a form of risk management, primarily used to hedge against the risk of a contingent or uncertain loss, such as death, severe illness, *etc.* The insured receives a contract, called the insurance policy, which details the conditions and circumstances under which the insurer will compensate the insured. The amount of money charged by the insurer to the Policy holder for the insurance policy is called the premium and the insured amount is paid once the event occurs. This premium cost is calculated by actuarial models. Actuarial models provide frameworks for analysis, allowing to project probable outcomes based on past experience adjusted for known material changes in circumstances. They are usually expressed in mathematical terms, and are typically designed to be consistent with fundamental principles of actuarial science. These models used are classified as either deterministic or stochastic. They are simplified representations of possible outcomes relative to future contingent events. A "contingent event" is an event whose occurrence, timing, or severity is uncertain. This contingent event can be death due to disease, sickness or accident, *etc.* Actuarial models may contain many elements and are usually based upon multiple interrelated assumptions about various aspects of risks associated with the event of interest. These models use probability of events and decrement models, Bowers *et al.* (1997).

Actuarial modeling is widely accepted to bring reliable methods for pricing the insurance contracts. As of the present there is no insurance company that provides any insurance policy to the HIV/AIDS patients. The HIV/AIDS patients and their dear ones involved in diagnosis process face lot of problems in terms of finance, so introducing such a plan will be beneficial in public interest. An insurance plan is introduced for patients suffering from Acute lymphoblastic leukemia (ALL), Grover *et al.* (2018) and HIV/AIDS Grover *et al.* (2021) based on the survival probabilities. This study considers the estimation the survival probability in presence of the prognostic factors and hence estimating the premium cost. The study suggests early enrolment in the insurance plan. The premium cost is lower in the earlier stage.

2. Methodology

A retrospective study is conducted for HIV/AIDS patients from a hospital located in Delhi. A total of 767 patients are selected for this study out of 5894 patients after a complete-case analysis. The prognostic factors taken into study are age of the patients, smoking and drinking habit, drug addiction and modes of transmission. There are four modes of transmission 1- IDU (Injection Drug Users), 2- HOMO-MSM (sex with men to men), 3-HETERO (infected through sex) and 4-Blood (infected through blood transfusion). There are 556 males and 211 females. 84 of patients had smoking habit and 320 had drinking habit. Apart from this 685 were drug edict. Out of these four modes of transmission 10 got infected by mode 1, 6 by mode 2, 688 by mode 3 and remaining by mode 4.

The existing clinical staging of HIV/AIDS infection established by WHO in Table 1 is redefined into two categories for the study. The CD4 count is the primary factor considered for categorization and follow-up time is taken up for survival estimation. Based on the CD4 count the four categories mentioned in Table 1 are categorized further as:

Table 2: Categorising the existing stages of HIV/AIDS in symptomatic patients

HIV-associated symptoms	CD4 per microlitre	Category
Mild symptoms or Advanced symptoms	200-499	Category 1
Severe symptoms	<200	Category 2

The patients with mild or advanced symptoms having CD4 count from 200 to 499 are placed in Category 1 and patients with severe symptoms having CD4 count less than 200 are placed in Category 2 (Table 2). Throughout the article, three groups are considered for analysis. These are Category 1, Category 2 and the third is combined, when all the symptomatic patients are taken together including Category 1 and Category 2.

Let $\mu(t)$ be the hazard rate of a HIV/AIDS patient at time i. Cox-PH model is used to estimate the hazard rate in all three scenarios (viz, all the 767 patients and patients in the two categories described in Table 2), in the presence of prognostic factors. The purpose of this model is to evaluate simultaneously the effect of several prognostic factors on the survival of the patients. The Cox-PH model is defined as,

$$\mu(t) = \mu_0(t) \cdot \exp\left(b_1 x_1 + b_2 x_2 + ... + b_p x_p\right)$$

Where, x_i is the $i^{th}(i = 1, 2, ..., p)$ prognostic factor, with coefficient b_i and $\mu_0(t)$ is baseline hazard rate.

Further, the probability of surviving one year (t) with hazard rate $\mu(t)$ is given by:

$$p_x = \exp\left\{-\int_x^{x+1} \mu(t)dt\right\}$$

These probabilities are used to obtain death probabilities in the presence of prognostic factors.

2.1. Premium model

Models for insurance are designed to reduce the financial impact of untimely death. Insurance systems are established to reduce the adverse financial impact of some type of random event; here death is the primary event. To calculate the premium cost for HIV/AIDS patients a discrete model is considered Luptáková and Bilíková (2014), Haberman and Pitacco (1998). Deterministic model is derived from the principle of an unreal set and the equivalence principle which are basic principles of the classical methods Norberg (2000), Slud (2001). The estimated death probabilities of the HIV/AIDS patients (q_x) are used to calculate insurance premium for the given time period (t). We have considered the model for one year of insurance. The payable insurance premium cost ($\overline{A}^1_{(x,i)}$) for the patient, with a rate of interest i is calculated as

$$\overline{A}^1_{(x,i)} = q_x.v + p_x.q_(x+1).v^2$$

where, $v = (1+i)^{(-1)}$ is the discount factor used to calculate the value of unit currency after one year based on compound interest with the rate of interest i.

3. Results

3.1. Kaplan-Meier estimates

Kaplan-Meier survival estimates for HIV/AIDS patients are shown in Table 3. The survival estimates for the HIV/AIDS patients for the first year are 0.969 (SE=0.015), 0.909 (SE=0.12), and 0.923 (SE=0.010) for Category 1, Category 2, and combined (including patients of Category 1 and Category 2) respectively. The highest and lowest survival rates in the first year are for Category 1 and Category 2, respectively. For the patients taken combined the survival decreases by 4.98% in the next year. Further, from 7th to 8th year then it declines by 7.28%, and shows a sharp decline after this (Figure 3). For the patients in Category 1 the survival decreases by 6.91% in the very next year. In the year from 2nd to 3rd and 7th to 8th the survival declines by 5.65% and 5.26% respectively. In between it looks like a plateau (Figure 4). For the patients in Category 2, the survival drops by 4.51% in the next year, and 7th to 8th the survival declines by 9.62%. Figure 5 also show sharp decline in survival in the initial years and then after the 8th year. Eventually, after 5 years the survival estimates decline by 14.08%, 15.58% and 13.42% respectively.

Table 3: Kaplan-Meier survival estimates for the HIV/AIDS patients

Time (Years)	Combined	% Change	Category 1	% Change	Category 2	% Change
1	0.923		0.969		0.909	
2	0.877	4.98	0.902	6.91	0.868	4.51
3	0.839	4.33	0.851	5.65	0.834	3.92
4	0.817	2.62	0.818	3.88	0.814	2.40
5	0.793	2.94	0.818	0.00	0.787	3.32
6	0.776	2.14	0.8	2.20	0.767	2.54
7	0.742	4.38	0.761	4.88	0.738	3.78
8	0.688	7.28	0.721	5.26	0.667	9.62
9	0.508		0.451		0.523	

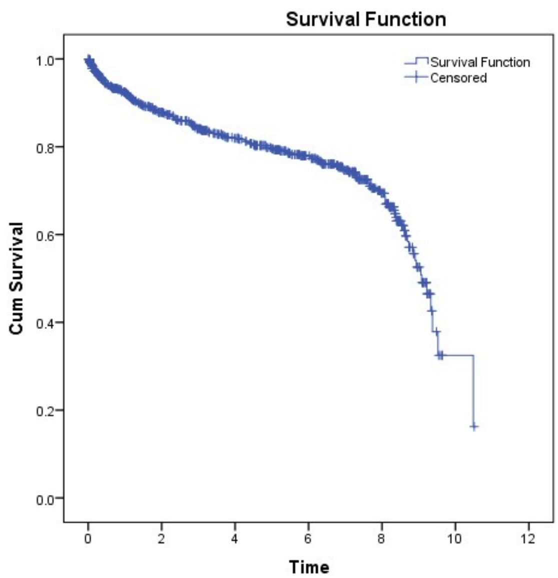

Figure 3: Kaplan Meier survival plot for the combined HIV/AIDS patients

3.2. Cox-PH regression survival estimates

Table 4 provides the Cox-PH model description for the combined HIV/AIDS patients. The model is highly significant with -2 log-likelihood value (1885.682) and Chi-square value as 38.362.

Table 4: Model description of Cox-PH for the combined HIV/AIDS patients

Omnibus Tests of Model Coefficients			
-2 Log Likelihood	**Overall (score)**		
	Chi-square	df	Sig.
1885.682	38.362	8	.000

Table 5: Model estimates of Cox-PH for the combined HIV/AIDS patients

Variables in the Equation								
	B	**SE**	**Wald**	**df**	**Sig.**	**Exp(B)**	**95.0% CI for Exp(B)**	
							Lower	**Upper**
Age	.018	.009	3.851	1	.050	1.018	1.000	1.036
Sex	-.285	.214	1.774	1	.183	.752	.495	1.144
Smoking	-.970	.204	22.672	1	.000	.379	.254	.565
DRUGS	.711	.323	4.836	1	.028	2.035	1.080	3.834
Alcohol	-.136	.194	.490	1	.484	.873	.597	1.277
MOT			1.497	3	.683			
MOT(1)	.042	.627	.005	1	.946	1.043	.305	3.563
MOT(2)	-.991	1.033	.921	1	.337	.371	.049	2.810
MOT(3)	-.211	.246	.736	1	.391	.810	.500	1.311

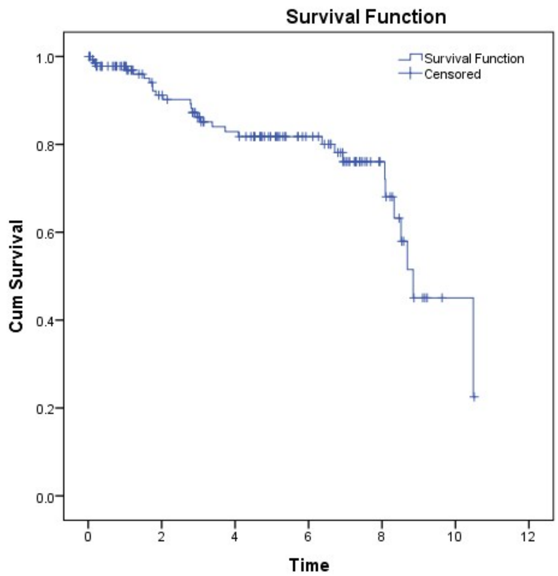

Figure 4: Kaplan Meier survival plot for the Category 1 HIV/AIDS patients

Table 5 explains the variables considered for the model of the combined HIV/AIDS patients. The variables include demography such as age and sex of the patient, smoking and drinking habit along with exposure to drugs. Apart from this method of transmission is one of the explanatory variables. Out of these variables we find that age (p-value= 0.050), habit of smoking (p-value= 0.000) and exposure to drugs (p-value= 0.028) are significant at 5% level of significance. Also, the hazard ratio suggests that for every one-year increase in age the risk will increase with a rate of 1.018. Similarly, for patients exposed to drugs will increase the risk with the rate 2.035.

Table 6: Cox-PH survival estimates for the combined HIV/AIDS patients

Time (Years)	Baseline Cum Hazard	Survival at mean of covariates	Std. Error	Cum Hazard
1	0.11	0.95	0.01	0.06
2	0.20	0.90	0.01	0.11
3	0.28	0.86	0.01	0.15
4	0.34	0.83	0.02	0.18
5	0.40	0.81	0.02	0.21
6	0.45	0.79	0.02	0.24
7	0.51	0.76	0.02	0.27
8	0.61	0.72	0.02	0.32
9	0.89	0.62	0.03	0.47

Table 6 provides the survival estimates for the combined HIV/AIDS patients obtained using Cox-PH regression. The estimated survival in the first year of follow-up is 0.95 and declines to 0.90. Also, after the 3rd year drops to 0.86 and further dips to 0.62 in the 9th year. Figure 6 shows the survival plot for the same and depicts a declining slope till 8th year and then drops.

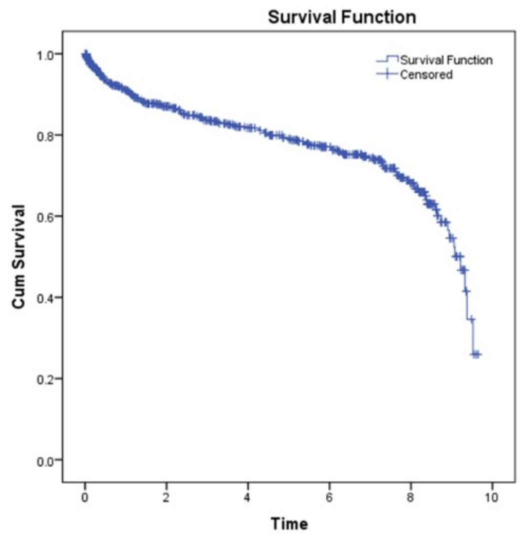

Figure 5: Kaplan Meier survival plot for the Category 2 HIV/AIDS patients

Table 7: Model description of Cox-PH for the Category 1 HIV/AIDS patients

Omnibus Tests of Model Coefficients			
-2 Log Likelihood	**Overall (score)**		
	Chi-square	df	Sig.
204.944	28.099	8	.000

Table 7 provides the Cox-PH model description for the HIV/AIDS patients in Category 1. The model is highly significant with lowest -2 log-likelihood value (204.944) and Chi-square value as 28.099.

Table 8: Model estimates of Cox-PH for the Category 1 HIV/AIDS patients

Variables in the Equation								
	B	**SE**	**Wald**	**df**	**Sig.**	**Exp(B)**	**95.0% CI for Exp(B)**	
							Lower	**Upper**
Age	.029	.025	1.392	1	.238	1.029	0.981	1.080
Sex	-.735	.847	0.753	1	.386	.480	.091	2.522
Smoking	-.351	.510	0.474	1	.491	.704	.259	1.912
DRUGS	1.892	.682	7.694	1	.006	6.634	1.742	25.257
Alcohol	-1.642	.766	4.599	1	.032	.194	.043	0.868
MOT			4.351	3	.226			
MOT(1)	.773	1.151	.451	1	.502	2.167	.227	20.689
MOT(2)	-13.104	464.703	.001	1	.978	.000	.000	
MOT(3)	-.991	.557	3.173	1	.075	.371	.125	1.105

Table 8 explains the variables considered for the model for the Category 1 HIV/AIDS patients. The variables include demography such as age and sex of the patient. Smoking and

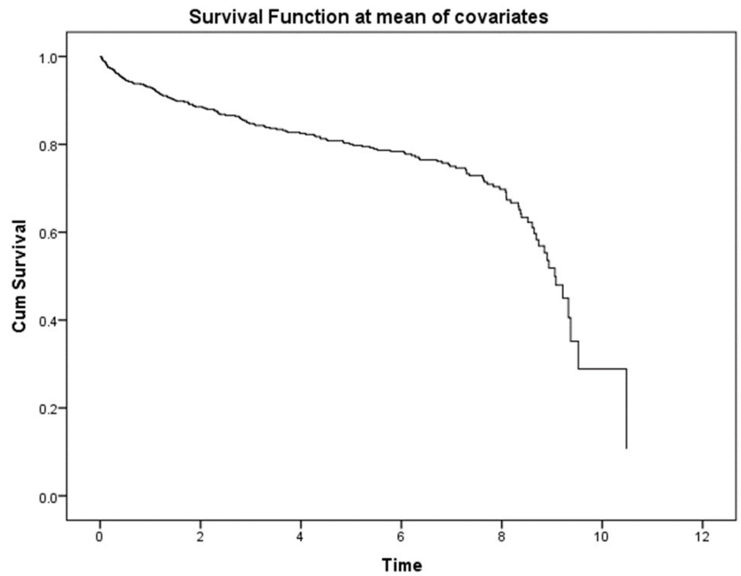

Figure 6: Cox-PH cumulative survival plot for the combined HIV/AIDS patients

drinking habit along with exposed to drugs. Apart from this method of transmission is also taken into care. Out of these variables we find that exposure of drugs (p-value= 0.006) and habit of alcohol intake (p-value= 0.032) are significant at 5% level of significance. Here, for the patient exposure to drugs, the risk will increase at a rate of 6.634 for each unit increase in drug exposer.

Table 9: Cox-PH survival estimates for the Category 1 HIV/AIDS patients

Time (Years)	Baseline Cum Hazard	Survival at mean of covariates	Std. Error	Cum Hazard
1	0.08	0.98	0.11	0.02
2	0.14	0.97	0.18	0.03
3	0.34	0.93	0.42	0.07
4	0.63	0.88	0.74	0.13
5	0.69	0.87	0.80	0.14
6	0.77	0.86	0.88	0.15
7	0.87	0.84	0.97	0.17
8	1.19	0.79	1.25	0.24
9	2.19	0.65	1.83	0.44
10	14.41	0.06	0.88	2.86

Table 9 provides the survival estimates for patients in Category 1 obtained by using Cox-PH regression. The estimated survival in the first year of follow-up is quite high (0.98) and reduces slightly in the next year. After 3rd year the survival estimate drops from 0.93 to 0.88 and further dips to 0.65.

Figure 7 shows the Cox-PH cumulative survival plot for the Category 1 HIV/AIDS

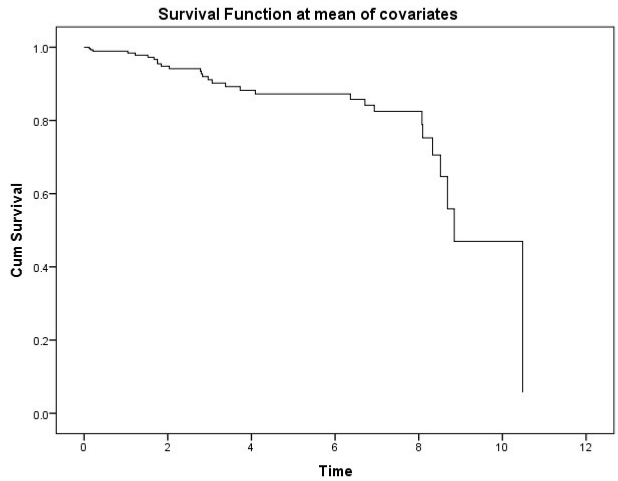

Figure 7: Cox-PH cumulative survival plot for the the Category 1 HIV/AIDS patients

patients indicting a drop in survival at 3rd and 8th year.

Table 10: Model description of Cox-PH for the Category 2 HIV/AIDS patients

Omnibus Tests of Model Coefficients			
-2 Log Likelihood	**Overall (score)**		
	Chi-square	df	Sig.
1512.359	32.131	8	.000

Table 10 provides the Cox-PH model description for the HIV/AIDS patients in Category 2. The model is highly significant with lowest -2 log-likelihood value (1512.359) and Chi-square value as 32.131.

Table 11: Model estimates of Cox-PH for the Category 1 HIV/AIDS patients

Variables in the Equation								
	B	**SE**	**Wald**	**df**	**Sig.**	**Exp(B)**	**95.0% CI for Exp(B)**	
							Lower	**Upper**
Age	.015	.010	2.383	1	.123	1.015	0.996	1.035
Sex	-.236	.230	1.057	1	.304	.790	.503	1.239
Smoking	-1.110	.223	24.761	1	.000	.330	.213	.510
DRUGS	.457	.388	1.388	1	.239	1.580	0.738	3.381
Alcohol	.082	.208	.155	1	.693	1.086	.722	1.633
MOT			0.119	3	.989			
MOT(1)	-.052	.762	.005	1	.946	0.950	.213	4.229
MOT(2)	-.357	1.040	.117	1	.732	.700	.091	5.379
MOT(3)	-.025	.282	.008	1	.930	.976	.562	1.695

Table 11 explains the variables considered for the model for the Category 2 HIV/AIDS patients. The variables include demography such as age and sex of the patient. Smoking and drinking habit along with exposed to drugs. Apart from this method of transmission is also taken into care. Out of these variables we find that only habit of smoking (p-value = 0.000) is significant at 5% level of significance.

Table 12: Cox-PH survival estimates for the Category 2 HIV/AIDS patients

Time (Years)	Baseline Cum Hazard	Survival at mean of covariates	Std. Error	Cum Hazard
1	0.11	0.94	0.01	0.07
2	0.22	0.88	0.01	0.12
3	0.27	0.85	0.02	0.16
4	0.32	0.83	0.02	0.18
5	0.37	0.81	0.02	0.21
6	0.43	0.78	0.02	0.25
7	0.49	0.75	0.02	0.28
8	0.57	0.72	0.03	0.33
9	0.83	0.62	0.04	0.48

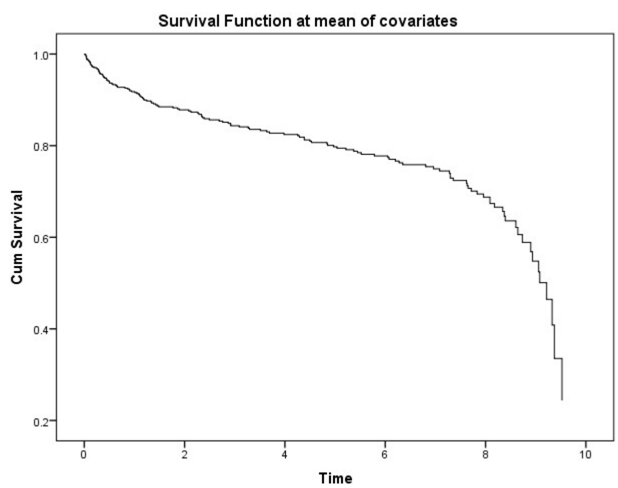

Figure 8: Cox-PH cumulative survival plot for the the Category 2 HIV/AIDS patients

Table 12 provides the survival estimates for patients in Category 2 obtained by using Cox-PH regression. The estimated survival in the first year of follow-up is 0.94 and declines to 0.88. Also, after the 5th year it goes from 0.81 to 0.78 in the 6th year and further dips to 0.62 in the 9th year.

Figure 8 shows the survival plot for the Category 2 depicts a drop in the survival first two years and then after the 8th year. In-between the survival declines slowly.

3.3. Calculation of premium cost

The survival estimates of Cox-PH regression are further utilised for the estimation of the premium cost. Table 13 shows the cost of the premium for all the HIV/AIDS patients combined and also for the patients in Category 1 and 2. Here, rupees one hundred is taken as sum insured and the cost of the premium to be paid is estimated. The estimated premium cost for HIV/AIDS patients cumulatively, Category 1 and 2 is Rs. 14.59, Rs. 4.16 and Rs. 16.77 respectively. Cumulatively, there is 5% decline in survival from 1st to 2nd year and from 7th to 8th year. In the same manner the premium cost increases by 48.94% and 22.27% respectively. Here we see that the patients under Category 1 have lowest premium cost. But in the very next 2 subsequent years the premium cost for Category 1 is almost doubled to Rs. 8.82 (112.09% rise from the previous year) and then shoots to Rs. 16.99 (92.65% rise from the previous year. In Category 2 the premium cost increases from Rs. 16.77 to Rs. 23.92 (42.62% jump) in the first year. Overall, for the five years the rise in premium cost is 142.66%, 487.79% and 114.11% respectively for the three categories.

Figure 9 shows the comparison of survival estimates (primary-axis) and premium cost (secondary-axis) for all the patients combined, in Category 1 and 2. The increasing trend of premium cost is followed by the decreasing survival estimates over the follow-up years. It clearly reflects that throughout the year, premium cost for Category 1 is lowest of all.

Table 13: Cost of premium for the HIV/AIDS patients

	Survival Estimates			Premium Cost		
Time (Years)	**Combined**	**Category 1**	**Category 2**	**Combined**	**Category 1**	**Category 2**
1	0.95	0.98	0.94	14.59	4.16	16.77
2	0.90	0.97	0.88	21.73	8.82	23.92
3	0.86	0.93	0.85	27.12	16.99	28.06
4	0.83	0.88	0.83	31.67	22.36	31.86
5	0.81	0.87	0.81	35.40	24.44	35.91
6	0.79	0.86	0.78	38.97	27.00	39.92
7	0.76	0.84	0.75	43.61	32.59	44.53
8	0.72	0.79	0.72	53.33	47.47	53.75
9	0.62	0.65	0.62			

4. Conclusion

The survival estimates of the HIV/AIDS patients are obtained using Kaplan-Meier and Cox-PH regression methods. These estimates are obtained for the patients in three scenarios, Category 1, Category 2 and combined. The estimates obtained using Cox-PH regression gave better estimates than that of Kaplan-Meier. For the patients taken combined, age, smoking habit and exposure to drugs are significant predictors. In Category 1 the habit of smoking and alcohol consumption are the significant predictors whereas in Category 2 only smoking habit is the significant predictor. The fitted model in all three scenarios is highly significant. Till 7 years the overall survival estimates are more than 75%. This high survival estimates provide great evidence to introduce a yearly insurance plan for the HIV/AIDS patients.

The suggested yearly insurance plan assures a sum of Rs. 100 against the premium of Rs. 14.59, Rs. 4.16 and Rs. 16.77 in the three scenarios respectively, in case of death. The best premium is for the patient in Category 1 since they have to pay very less as compared

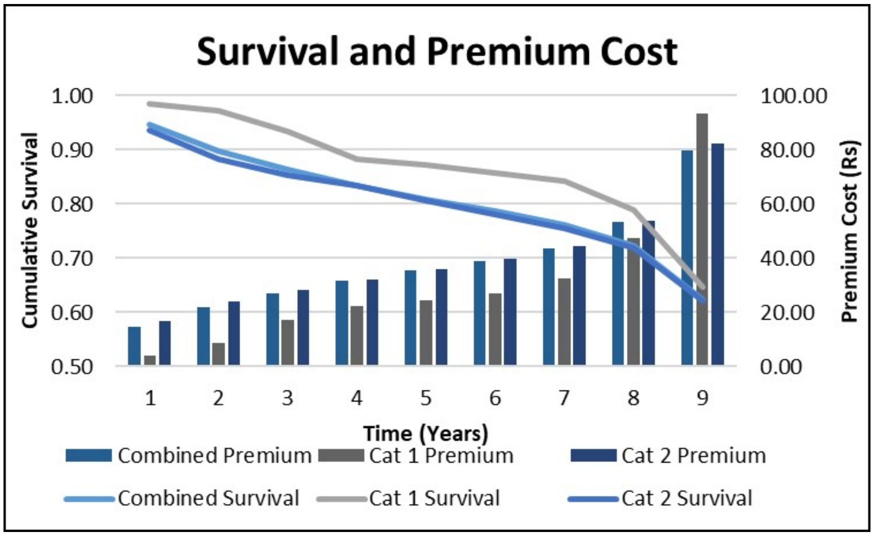

Figure 9: Comparison of survival estimates (primary-axis) and premium cost (secondary-axis) for all the HIV/AIDS patients

to the others. For a five-year difference the premium cost increases by 142.66%, 487.79% and 114.11% respectively in the three scenarios. So, it is recommended to opt for the insurance as early as possible because the premium cost keeps increasing over the time as the survival estimates decline.

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