Determinants of survival in stroke patients: application of Cox proportional hazards regression model

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Research Article

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Abstract

Objectives

Evidences showed that stroke is one of the most leading causes of death worldwide, with approximately 11.9 million new stroke patients occurring each year. Thus, the current study aimed to evaluate survival time of stroke patients and its determinants in Debre Berhan comprehensive specialized hospital.

Study design and methods:

A retrospective study was conducted on 259 stroke patients enrolled from 1st September 2020 to 1st December 2021. Kaplan-Meier curve and Log-rank test were used. Bivariate and multivariable Cox-PH regression models were also applied at 95% confidence level. Finally, both graphical and Schoenfeld residuals tests were used to the Cox-PH model assumptions.

Results

The mortality rate of stroke patients was 25.12%, and median survival time was 4.438 months. Female patients were 2.894 times more likely to die than males (AHR = 2.894, 95%CI: 1.574, 5.320). Patient age also suggested that the probability of death increased 1.041-fold for each additional month of patient (AHR = 1.041, 95%CI: 1.017, 1.065). Patients with hypertensive stroke were 2.575 times more likely to die than those without hypertension (AHR = 2.575, 95%CI: 1.295, 5.121). It has been also shown that patients with heart disease are 1. 483 times more likely to die than patients without heart disease (AHR = 1.483, 95%CI: 1.059, 1.972).

Conclusion

The prevalence of stroke mortality is relatively high. The patient's gender, age, hypertension, and heart disease have been shown to be contributing factors to a reduced survival time of stroke patients. Therefore, stroke patients with hypertension and heart disease, especially women, need special attention.

Introduction

According to World Health Organization (WHO), stroke is defined as a rapidly developing sign of focal (or global) impairment of brain function, with symptoms lasting more than 24 hours or dying without any apparent cause other than vascular origin (there is no apparent cause other than vascular origin) (Kassaw Asres et al., 2020). It is a catastrophic and incapacitating cerebrovascular disease, with significant residual defects leading to multiple losses (Kassaw Asres et al., 2020). Prior to 2018, it was the third leading cause of death in the world (Donkor, 2018), with high mortality and morbidity in low and

middle income countries, however, is now the second leading cause of deaths (Ababu & Getahun, 2022; Katan & Luft, 2018; Nkoke et al., 2015).

Based on the latest global burden of disease report, 11.9 million new strokes occur worldwide, with one in eight strokes (12%, 6.5 million) deaths worldwide, and it killed one person every 5 seconds, it is the second most common cause of death in the world (Gufue et al., 2020). In the absence of significant global public health response, stroke is projected to increase to 23 million new cases and 7.8 million deaths annually by the end of 2030 (Ababu & Getahun, 2022). Despite, geographic variation in stroke rates around the world is low, unfortunately, most stroke burdens borne by low- and middle-income countries (A. S. Kim et al., 2015). The age-adjusted stroke mortality rate is 89.82 per 100,000 population (Gufue et al., 2020).

In sub-Saharan Africa, including Ethiopia, there are no well-established stroke studies (Adeloye, 2014). Although the exact burden of stroke in Ethiopia is not known, it is believed to be on the rise and strokes account for 2.5% of all hospital admissions and 13.7% of medical admissions (Gufue et al., 2020). According to the latest WHO figures released in 2018, the number of deaths from stroke in Ethiopia reached 32,859, equivalent to 5.38% of the total number of deaths. The mortality rate by age is 74.87 per 100,000 population, Ethiopia ranks 87th in the world according to the life expectancy of Ethiopia in the world (www.worldlifeexpectancy.com/Ethiopia-stroke, Accessed March 11, 2022).

Furthermore, in Ethiopia, as in other developing countries, resources for stroke care and rehabilitation are inadequate (Alemayehu, 2013). Despite the alarming threat of stroke as a major public health problem in Ethiopia, the epidemiology of stroke in Ethiopia is not well understood. Stroke patients are often inadequately treated and discharged without appropriate rehabilitation services. This is a series of effects in saving the lives of patients, especially in developing societies where hemorrhagic strokes characterized by severe neurological symptoms are very common (Alemayehu, 2013; Fekadu et al., 2019).

The burden of stroke in Ethiopia can be increased due to demographic changes and poor management of key risk factors for stroke such as hypertension, heart disease, obesity, diabetes and smoking (Deresse & Shaweno, 2015). Moreover, hypertension remains the more leading risk factor of stroke (Ababu & Getahun, 2022; Alene et al., 2020; Alhazzani et al., 2018; Beza Mulat, 2016; Dabilgou et al., 2020; Deresse & Shaweno, 2015; Donkor, 2018; Viderman et al., 2020; Wu et al., 2019). Stroke patients with heart disease were more likely to die than patients free from heart disease (Ababu & Getahun, 2022; Ballotta et al., 2007; Beza Mulat, 2016; Viderman et al., 2020). In addition, diabetes mellitus(Alene et al., 2020; Ballotta et al., 2007; Beza Mulat, 2016), baseline complication (Ababu & Getahun, 2022; Kassaw Asres et al., 2020), stroke type (Ababu & Getahun, 2022), older age (Alhazzani et al., 2018; Beza Mulat, 2016; Kassaw Asres et al., 2020; Wu et al., 2019), smoking, alcohol drinking (Beza Mulat, 2016; Wu et al., 2019), sex of patients (Ababu & Getahun, 2022; Wu et al., 2019) were also identified as major factors contributing to stroke patients mortality. Because stroke is largely preventable, understanding the risk factors for stroke is an important step in reducing the incidence of stroke and the burden of the resulting illness (Deresse & Shaweno, 2015).

Despite, absence of previous evidence about stroke prevalence and its determinants in the current study area, the aforementioned factors found to be significantly associated with stroke deaths in other settings of Ethiopia (Beza Mulat, 2016; Gedefa et al., 2017; Kassaw Asres et al., 2020). However, most of these studies were used a logistic regression model, but in this case the censored data to be the result of missing values in the dependent variable, so logistic regression does not take into account the censored observations. Therefore, further research and implementation of analytical methods suitable for preventive strategies is needed, especially in current research areas. Thus, this study aimed to evaluate survival time of stroke patients and associated determinants in Debre Berhan comprehensive specialized hospital (DBCSH) from 1st September 2020 to 1st December 2021.

Methods And Materials

Study setting, design and period

A hospital-based retrospective study design was conducted at the Debre Berhan Comprehensive Specialized Hospital (DBCSH) from 1st September 2020 to 1st December 2021. Debre Berhan is one of Ethiopia's administrative cities in the Amhara region, the capital of the North Shewa Zone, 130 km northeast of Addis Ababa. The city has nine kebeles (the smallest administration level in Ethiopia) with a total population of 94, 829, of which 50.8% are women. There are approximately 22 medical facilities, 2 hospitals (1 private hospital and 1 government referral hospital), 3 medical centers and 17 private clinics in the city (Sharew et al., 2018; Tesfay & Habtewold, 2015). DBRH has a 150-bed facility and a catchment area for 2.8 million people.

Target and Study Population

All stroke patients admitted to the DBCSH intensive care unit (ICU) were used as the target population. The study population consisted of patients examining all medical histories of stroke, including hypertension, heart disease, diabetes, stroke types, and diagnosis of baseline complications that led to death during the study period.

Inclusion and Exclusion Criteria

Included were stroke patients who were admitted to ICU wards of DBCSH for the required period and those who had complete data on the variables of interest. Patients outside the interval period who have insufficient information about either a factor variable in the registry book or card not included in the study.

Sample and sampling technique

All stroke patients who were followed up between 1st September 2020 and 1st December 2021 and met the eligibility criteria were selected, then a total of 259 patients were included.

Study variables

The response variable was the time to death (measured in days) from the start of anti-stroke treatment to the date of the patient's death or censoring. While, explanatory variables assumed to influence the time to death of stroke patients with corresponding categories were sex (male, female), age patients' in years, residence (urban, rural), hypertension (yes, no), cardiac diseases (yes, no), diabetes mellitus(yes, no), stroke subtypes (ischemic, hemorrhagic, both), baseline complication (yes, no).

Data processing and analysis

The collected data was entered into SPSS software version 25 for cleaning, coding and editing and exported to STATA software version 16 for analysis. Data exploration was done to see if there were any weird code or items that didn't make sense, and then edits were made. The response variable is survival time, defined as "years elapsed from the date of first stroke treatment to death" and coded as 1 or as zero for subjects who did not die (censored). For categorical variables, a descriptive analysis was performed and the results were expressed as a percentage of frequency and mean with the standard deviation for the continuous variables.

To compare time to death between different patient groups, we used Kaplan-Meier curve and Log-rank test to compare and test survival functions between different patient groups using different categorical predictor.

Bivariate and multivariable Cox proportional hazard models were also applied to identify stroke-related predictors. Here, a variable having $p < 0.25$ was considered eligible for multivariate analysis in Cox proportional hazard analysis. Whereas, variables with p-values of 0.05 or less were reported to be significantly associated with patient survival in a multivariable Cox proportional hazards analysis. Adjusted hazard ratio (AHR) with 95% confidence intervals was used to determine the association between patient survival and predictors. Finally, the proportional hazard assumptions are graphically and statistically evaluated using a log-minus-log survival curve and a Schoenfeld residual, respectively to satisfy the assumptions of Cox PH model.

Ethics approval and consent to participate

Ethical approval was obtained from the Institutional Review Board (IRB) of Debre Berhan University using the assigned protocol number (P004/2021). And we got formal permission from DBCSH chief executive director. However, written informed consent was not obtained from the participants, as the study data were retrospectively extracted from medical records. There were no study participants below the age of 18 years. All methods were carried out in accordance with relevant guidelines and regulations.

Results

Sociodemographic and clinical characteristics of stroke patients

During the study period from 1st September 2020 to 1st December 2021, a total of 259 stroke patients were treated at DBCS Hospital. From the total patients, this study included 203 stroke patients with complete data on associated variables of interest. Of the 203 stroke patients, 152 (74.88%) were censored or did not live to see the event, and 51 (25.12%) died. Of the total patients included, 99 (48.77%) were male, of whom 17 (33%) died, while 104 were female, of whom 34 (67%) died. Among 124 (61.08%) patients with hypertension, of which 40 patients (78.4%) died and 79 (38.92%) patients without hypertension, of which 11 patients (21.5%) died (Table 1).

Of all patients, 95 (46.80%) were urban patients, of those 25 (49%) died, and 108 (53.20%) were rural patients, of which 26 (51%) died. Of the patients included in the study, 62 (30.54%) had heart disease, 17 (33%) died, and 34 of 141 (69.46%) who did not have heart disease 34 (67%) died. There are 129 (63.55%) ischemic patients, of which 36 (70.5%) have died, 56 (27.59%) are non-heamorrhagic patients, 12 (23.5%) have died and 18 (9.59%) suffered from both types of stroke, of which 3 (5.8 %) died (Table 1).

Table 1 Sociodemographic and clinical characteristics of stroke patients at DBCSH from 1st September 2020 to 1st December 2021 follow-up periods.

Variable	categories	Frequency (%)	Death (%)	Censored (%)
Sex	Male	99 (48.77)	17 (33)	82 (54)
	Female	104 (51.23)	34 (67)	70 (46)
Hypertension	No	79 (38.92)	11 (21.5)	68 (44.7)
	Yes	124 (61.08)	40 (78.4)	84 (55.2)
Residence	Urban	95 (46.80)	25 (49)	70 (46)
	Rural	108 (53.20)	26 (51)	82 (54)
Cardiac disease	No	141 (69.46)	34 (67)	107 (70.4)
	Yes	62 (30.54)	17 (33)	45 (29.6)
Diabetes mellitus	No	158 (77.83)	44 (86.3)	114 (75)
	Yes	45 (22.17)	7 (13)	38 (25)
Baseline complication	No	98 (48.28)	18 (35.3)	80 (52.6)
	Yes	105 (51.72)	33 (64)	72 (47.3)
Stroke type	Ischemic	129 (63.55)	36 (70.5)	93 (61)
	Haemorrhagic	56 (27.59)	12 (23.5)	44 (29)
	Both	18 (9.59)	3 (5.8)	15 (10)
Age	**Min.**	**Max.**	**Mean**	**Std. Dev.**
	22	96	61.54	14.32
Time	**N**	**Median (50 %)**	**[95%**	**CI]**
	203	4.438	4.02	4.86

Among patients considered in the study, 45 (22.17%) were diabetic, of which 7 (13%) died, 158 (77.83%) were non-diabetic in which 44 (86.3%) died. Of the total patients, 105 (51.72%) had baseline complications, of which 33 (64%) died, 98 (48.28%) had no baseline complications of which 18 (35.3%) dead. The average age of the patients was 61.54 years, the oldest and youngest were 96 and 22 years, respectively, and the standard deviation was 14.32. Finally, the median survival time of patients was 4.438 months (Table 1).

Overall stroke patients' status

Of the total 259 stroke patients who were treated at DBCS hospital from 1st September 2020 to 1st December 2021 follow-up periods, 25.12% of them were died and the remaining 74.88% were survived

during the specified period (Figure 1).

Figure 1 shows stroke patients' status during the study periods.

Kaplan Meier Estimate of stroke patients

Figure 2 shows the overall survivor estimates from the Kaplan-Meier and hazard functions, and it shows a relatively large number of deaths that occurred early in stroke treatment (Figure 2 (a)). Similarly, patient risk or mortality increased significantly early in the follow-up period (Figure 2 (b)). This seems to be inversely proportional to the survival function, that is, the risk increases as the patient's survival decreases (Figure 2).

Figure 2 (a): Survival Function curve

Figure 2 (b): Hazard Function curve

Figure 2: The K-M plots of survival and hazard function of stroke patients at DBCSH during 1st September 2020 to 1st December 2021 follow-up periods.

Furthermore, plots of Kaplan-Meier survival function estimates for patients based on various categories of factors were also generated. For instance, the graph in Figure 3 (left) shows significant differences between patient sex groups. In other words, relatively high survival rates are observed in males. Similarly, Figure 3 (right) shows that better survival was observed in patients without hypertension or those without hypertension have a longer survival time than those with hypertension (Figure 3).

Figure 3: Plot of Kaplan-Meier curves by sex (left side) and hypertension (right side) of stroke patients at DBCSH, respectively, from 1st September 2020 to 1st December 2021 follow-up periods.

Log-rank test

In log rank test of equality of survival functions, a statistically significant difference in survival time was observed among patient groups of gender, hypertension, cardiac disease, and baseline complications at 5% level of significance. However, there are no statistically significant differences in survival experience between patient categories such as diabetes mellitus, stroke type, and residence (Table 2).

Table 2 Log-rank test in stroke patient characteristics for each categorical variables at DBCSH from 1st September 2020 to 1st December 2021 follow-up periods.

Predictor	Chi-square of log rank	df.	p-value
Sex	6.97	1	0.0083*
Residence	0.05	1	0.8182
Stroke type	1.71	2	0.4243
Hypertension	9.25	1	0.0024*
Cardiac disease	1.36	1	0.0394*
Diabetes mellitus	2.58	1	0.1085
Baseline complication	4.14	1	0.0420*

* P-value < 0.005 at 5% level of significant

Bivariate Cox PH regression model

Instead of immediate access to the all-inclusive Cox PH multiple regression model presented to determine baseline factors for stroke patient survival, bivariate analyses were performed at the 25% significance level to see the impact of each predictor on stroke patient survival. . Accordingly, predictors such as gender, age, hypertension, diabetes, heart disease and underlying complications were identified as contributing factors and candidates for multivariate analysis (Table 3).

Table 3 Bivariate Cox PH regression estimates of stroke patients at DBCSH from 1st September 2020 to 1st December 2021 follow-up periods.

Predictor	Category	CHR	P-value	75% CI
Sex	Male-reference	1		
	Female	2.103	0.012	1.174 3.767
Residence	Urban-reference	1		
	Rural	.940	0.824	.543 1.627
Age	None	1.037	0.000	1.016 1.058
Stroke type	Ischemic- reference	1		
	Hemorrhagic	.716	0.316	.372 1.376
	Both types	.585	0.372	.180 1.899
Hypertension	No- reference	1		
	Yes	2.627	0.005	1.347 5.124
Cardiac disease	No-reference	1		
	Yes	1.188	0.026	1.066 2.127
Diabetes mellitus	No- reference	1		
	Yes	.537	0.126	.242 1.192
Baseline complication	No-reference	1		
	Yes	1.767	0.052	.995 3.138

Multivariable Cox PH regression model

Based on the final fitted Cox PH regression estimation, the hazard ratio for females was 2.894, which implies that females had 2.894 times higher risk of death than males (95% CI: 1.574, 5.320, p = 0.001). Patients' age was also found to be a significant factor for their survival (AHR = 1.041, 95% CI: 1.017, 1.065 and p = 0.002). This suggests that the probability of death in stroke patients increases by 1.041 times as their age increases by one month. Patients with hypertensive stroke were 2.575 times more likely to die than those without hypertension (AHR = 2.575, 95% CI: 1.295, 5.121, p = 0.007). Furthermore, heart disease was also considered as one of the contributing factors to reduce the survival time of stroke patients, with an estimated hazard ratio of 1.483 (95% CI: 1.059, 1.972 and p = 0.042). The estimate indicated that stroke patients with heart disease were 1.483 times more likely to die than patients without heart disease (Table 4).

Table 4 Multivariable Cox PH regression estimates of stroke patients at DBCSH from 1st September 2020 to 1st December 2021 follow-up periods.

Predictor	Category	AHR	P-value	95% CI	
Sex	Male-reference	1			
	Female	2.894	0.001	1.574	5.320
Age	Continuous	1.041	0.002	1.017	1.065
Diabetes mellitus	No- reference	1			
	Yes	.630	0.271	.276	1.435
Hypertension	No- reference	1			
	Yes	2.575	0.007	1.295	5.121
Cardiac disease	No- reference	1			
	Yes	1.483	0.042	1.059	1.972
Baseline complication	No- reference	1			
	Yes	1.166	0.791	.596	1.972

Test of proportional hazard assumption

The global (overall) schoenfeld residual test was not significant (p = 0.110), indicating that the proportionality hypothesis is satisfied at the 0.05 significance level. In addition, almost each predictor showed no statistically significant p-values, implying that the corresponding hazard hypothesis should not be rejected (see Table 5).

Table 5 Schoenfeld residual estimates used for testing proportional hazards assumption among stroke patients at DBCSH from 1st September 2020 to 1st December 2021 follow-up periods.

Predictor	Category	rho		Df.	Prob.>
Sex	Female	0.012	0.01	1	0.924
Age	None	-0.040	0.09	1	0.769
Residence	Rural	-0.149	1.39	1	0.239
Stroke type	Hemorrhagic	0.057	0.18	1	0.673
	Both types	-0.232	2.77	1	0.096
Hypertension	Yes	-0.335	5.67	1	0.017
Cardiac Disease	Yes	-0.191	2.48	1	0.115
Diabetes Mellitus	Yes	0.033	0.06	1	0.814
Baseline Complication	Yes	-0.055	0.18	1	0.676
Global test			**14.35**	**9**	**0.110**

Graphical test of proportional assumption

In Figure 4 (a, b and c), -ln (-ln (survival)) cells are often referred to as "log-log" cells for each category of a nominally independent variable as a function of follow-up time that shows testing the proportional hazard hypothesis. Therefore, the curves are parallel to each other, implying that the assumption of proportional risk is not violated. Here, each estimate is obtained by adjusting for the other covariates. From Figure 4 (b), patients without diabetes unfortunately had a shorter survival time than patients with this disease.

Figure 4 (a): Patients' hypertesion status

Figure4 (b): Patients' diabetic mellitus status

Figure 4 (c): Patients' baseline complication

Figure 4: The -ln(-ln S(t)) vs time plot is the graphical test of proportional hazards (PH) assumption of Cox PH model using some stroke patients' health statuses, such as patients' hypertesion (a), diabetic mellitus (b), and baseline complication (c) statuses.

Discussion

The overall mortality of stroke patients was 25.12%, which is higher than the prevalence reported in other studies (Gufue et al., 2020; Walelgn et al., 2021) reported as 14.9% and 15.2%, respectively. However, it was lower than the mortality rates of 31.7%, 29.74%, and 27.2%, respectively, reported in studies (Ababu & Getahun, 2022; Kamabu et al., 2020; Kassie et al., 2019). On the other hand, the median survival time was

4.438 months and it is in full agreement with another study (Takashima et al., 2020), which indicated that the median follow-up was 4.3 months.

In the present study, gender was considered an important factor for stroke patient survival, in particular, the survival time of women was less than that of men. In other words, the risk of death in female patients is higher than in men. This is consistent with the results of previous studies (Ababu & Getahun, 2022; Wu et al., 2019), however, another study (Alhazzani et al., 2018) contradicts the study of us and concluded that men had a significantly higher mortality rate.

Along with other studies such as (Alhazzani et al., 2018; Beza Mulat, 2016; Chen et al., 2020; Fornage et al., 2018; Kassaw Asres et al., 2020), the survival time of elderly population of stroke patients was significantly shorter than that of younger patients. The implication is that stroke mortality has decreased among younger people. It also demonstrated in research (Furlan et al., 2021) that older adults are more likely to have a stroke with neurological severity, because older adults have more comorbidities (risk factors) and difficult to control for risk factors at optimal level.

In our study, hypertension was identified as an important mortality factor in stroke patients and this finding has been consistently supported by studies (Ababu & Getahun, 2022; Alene et al., 2020; Alhazzani et al., 2018; Beza Mulat, 2016; Dabilgou et al., 2020; Deresse & Shaweno, 2015; Donkor, 2018; Viderman et al., 2020; Wu et al., 2019). It can be inferred that stroke patients with hypertension are more likely to die than those without hypertension. Another study also showed that the association between blood pressure and stroke mortality was strong and direct, and that the absolute risk of high blood pressure-related stroke death increased with age (Hu et al., 2005). In the study, it also stated that the increased stroke risk commonly seen in people with high blood pressure can sometimes be related not only to the hypertension itself, but also to undiagnosed diabetes.

Moreover, in the present study, heart disease was also one of the significant contributing factors to shortening the survival time of stroke patients. In particular, stroke patients with heart disease have a higher risk of death than patients without heart disease, and other studies such as (Ababu & Getahun, 2022; Ballotta et al., 2007; Beza Mulat, 2016; Viderman et al., 2020) confirmed this conclusion. A study of heart failure as a risk factor for stroke (W. Kim & Kim, 2018) showed increasing evidence that heart failure itself increases stroke risk in different mechanisms, mainly due to thromboembolism.

However, in our study, diabetic stroke patients did not have a statistically significant difference with non-diabetic patients, another study (Wang et al., 2017) reported that diabetes was significantly associated with the risk of stroke and suggested that control of fasting plasma glucose (FPG), particularly in people with diabetes and taking antidiabetic drugs, sugar, which is important in preventing stroke.

Conclusions

This study reveals a relatively high stroke mortality rate. In addition, patients' gender, age, hypertension, and heart disease have been shown to reduce stroke survival. Therefore, stroke patients with

hypertension and heart disease, especially women, need special attention and should focus on non-communicable diseases and primary prevention of stroke.

List Of Abbreviations

AHR: Adjusted hazard ratio

CI: Confidence interval

Cox PH: Cox Proportional hazard

DBCSH: Debre Berhan Comprehensive Specialized hospital

ICU: Intensive care unit

WHO: World Health Organization

Declarations

Ethics approval and consent to participate

Ethical approval for the study protocol was provided by Debre Berhan University Institutional Review Board (IRB) with protocol number (P004/2021). Written informed consent was not obtained from study participants because of the study design was an institutional-based retrospective study. However, there were no study participants below the age of 18 years. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request

Competing interests

The author declare no any conflict of interest.

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Author’s contributions

A.W.K done study design, data management and analysis, interpretation, report writing, reviewing, and editing

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Additional information

Not applicable

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Figures

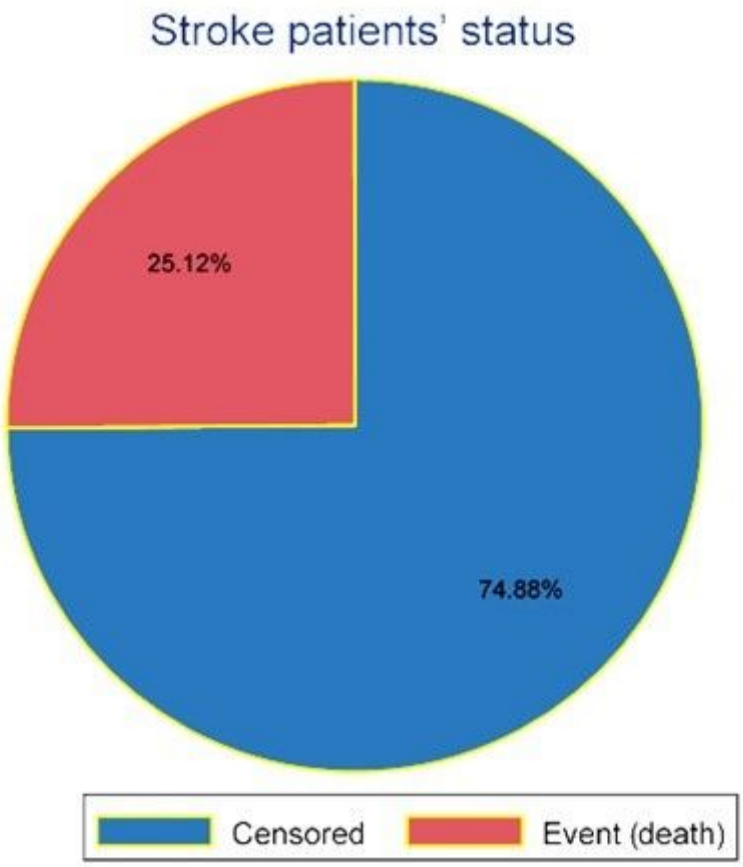
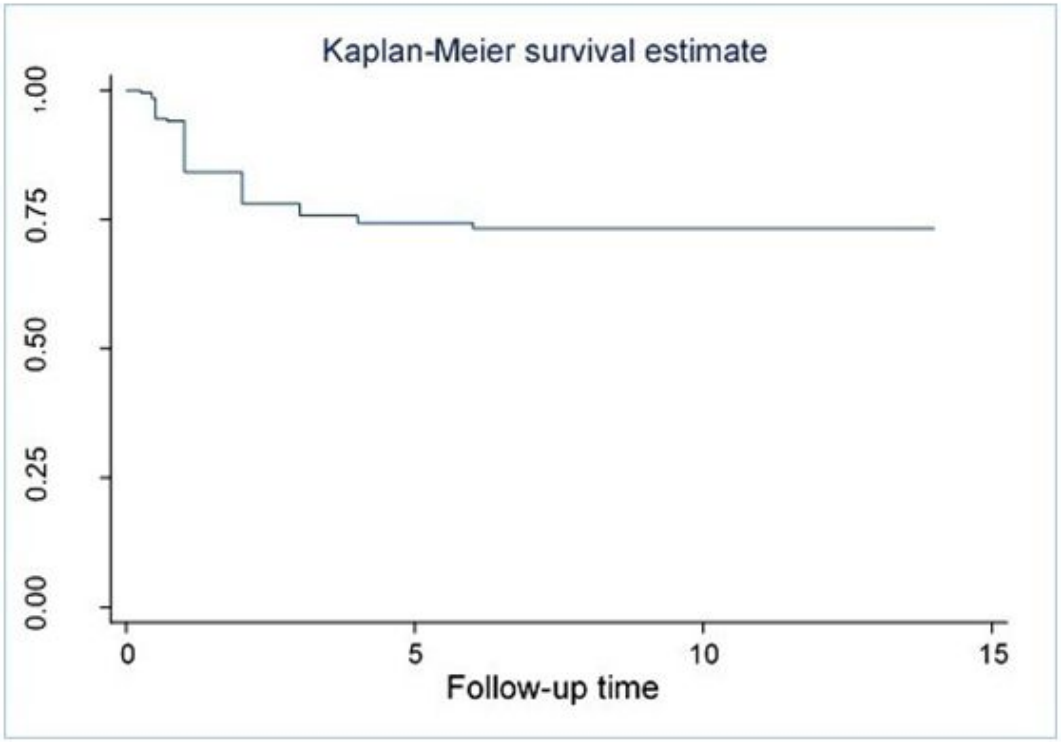


Figure 1

shows stroke patients' status during the study periods.



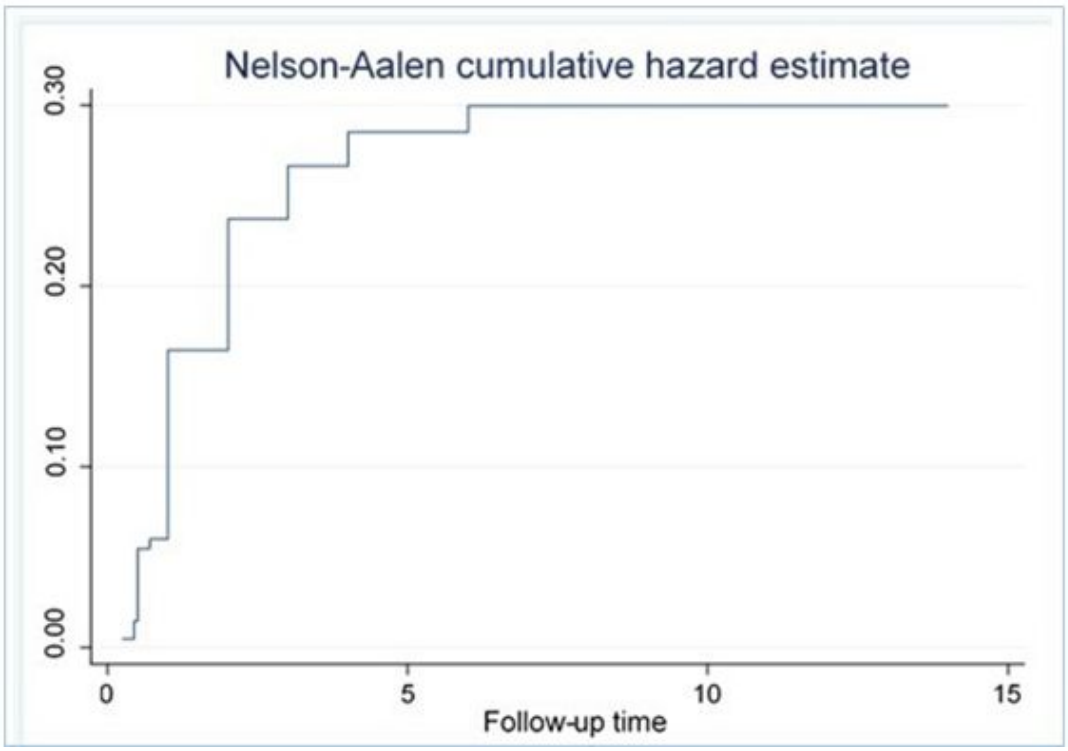


Figure 2

(a): Survival Function curve

(b): Hazard Function curve

The K-M plots of survival and hazard function of stroke patients at DBCSH during 1st September 2020 to 1st December 2021 follow-up periods.

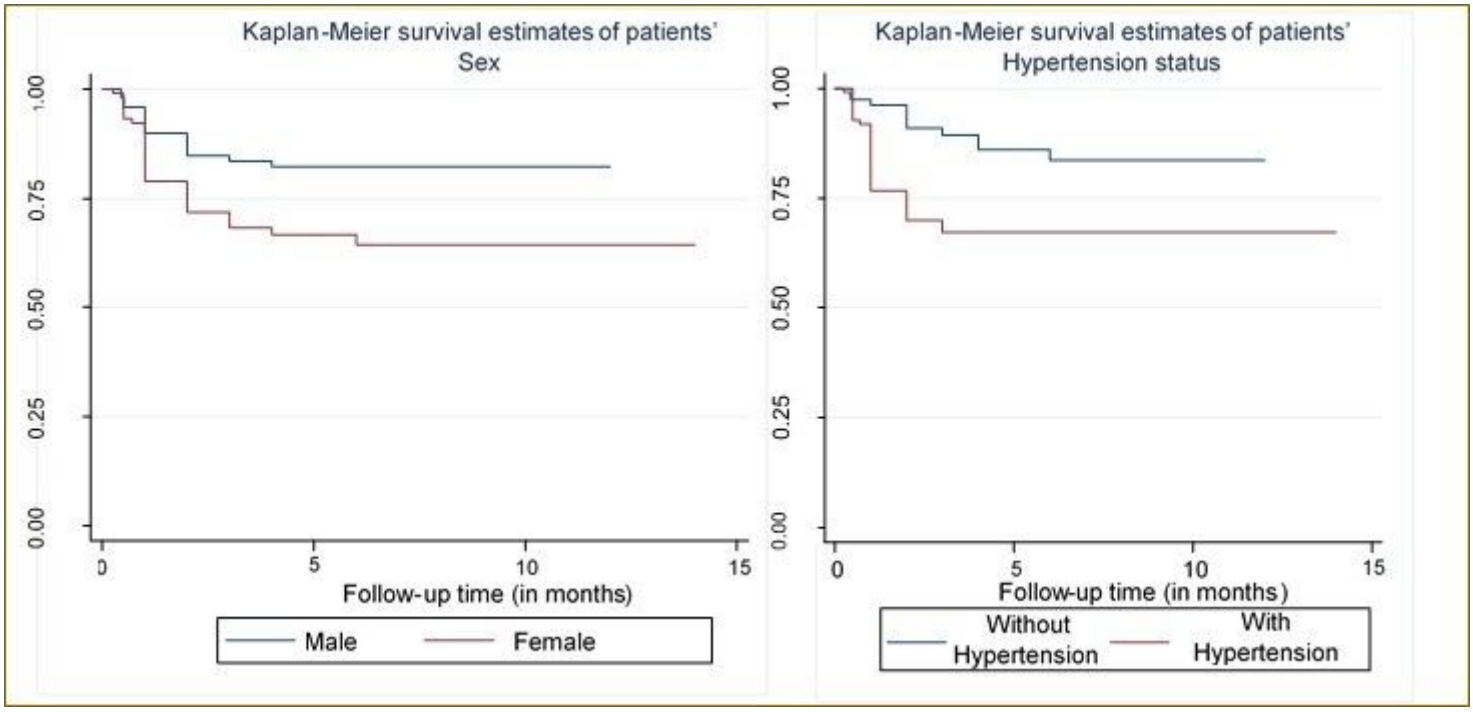
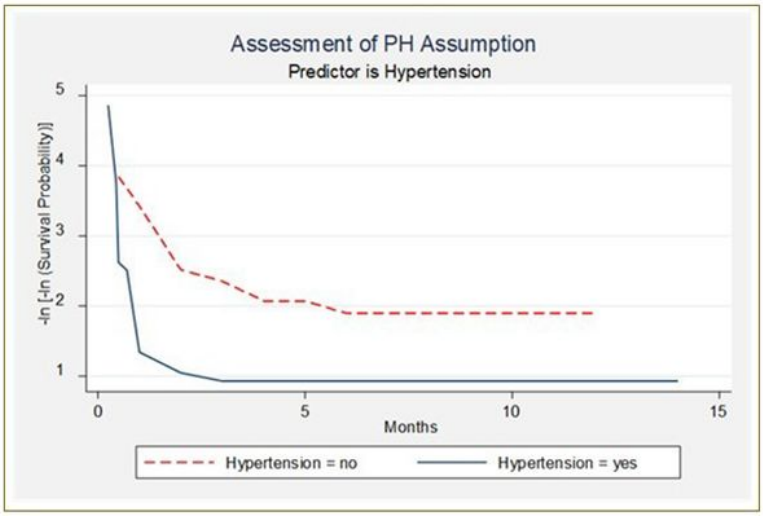
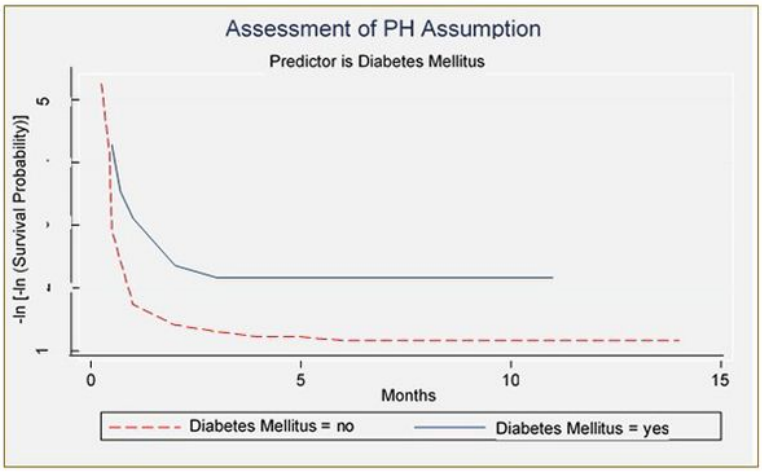


Figure 3

Plot of Kaplan-Meier curves by sex (left side) and hypertension (right side) of stroke patients at DBCSH, respectively, from 1st September 2020 to 1st December 2021 follow-up periods.





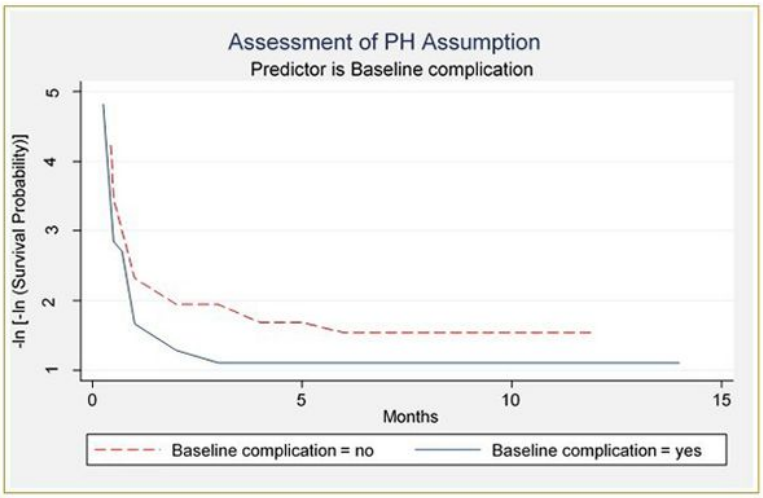


Figure 4

(a): Patients' hypertesion status

(b): Patients' diabetic mellitus status

(c): Patients' baseline complication

The -ln(-ln S(t)) vs time plot is the graphical test of proportional hazards (PH) assumption of Cox PH model using some stroke patients' health statuses, such as patients' hypertesion (a), diabetic mellitus (b), and baseline complication (c) statuses.