IRAETC Journal of Nursing and Health Care
ISSN (e): 3005-3838
Volume: 2 (2024), Issue: 1 (Jan-Feb)

OPEN ACCESS
iraetcjournals.com

Statistical Models for Evaluate to Efficacy of Chronic Kidney Disease Control Measure

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Original Research Article

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Citation:
Kannadasan Karuppaiah *et al.*, (2024); Statistical Models for Evaluate to Efficacy of Chronic Kidney Disease Control Measure. iraetc j. nur. health care; 2(1) 1-6.

Abstract:

Chronic kidney disease (CKD) is a potentially life-long condition that can result from kidney cancer or reduced kidney function. However, it is possible to slow or stop the progression of this disease before it reaches a critical stage where dialysis or surgery is the only option to save the patient's life. Timely diagnosis and proper treatment can significantly increase the chances of success. This paper introduces the shock model approach, which is utilized to assess the effectiveness of treatment for CKD patients in achieving the threshold level. The model is accompanied by graphical illustrations for ease of use.

Key Words: Chronic Kidney Disease, Non-Communicable Diseases, Glomerular Filtration Rate, Diabetes, Hypertension and Burr-XII distribution.

|| © IRAETC Publisher || **Publication History** - Received: 30.12.2023 || Accepted: 15.01.2024 || Published: 20.01.2024||

INTRODUCTION

Health and health issues are a matter of concern for the human being right from the origin of human life. WHO defined health as a state of complete physical, social, and mental wellbeing, and not merely the absence of disease or infirmity. The health system over the globe never before thought of splitting the terms of health into two broad categories such as Communicable and Noncommunicable Disease (NCD), had the firm belief that such a move might make more considerable distributional implications favoring the rich (Gwatkin, Guillot and Heuveline 1999[6]. Major noncommunicable diseases (NCD) identified are 'cardiovascular diseases (like heart attack and stroke), cancer, chronic respiratory diseases (such as chronic obstructed pulmonary disease and asthma), and diabetes apart from other co-morbid diseases WHO, 2010[15].

WHO defined chronic diseases as conditions of ill health which usually present with a prolonged period, produce, incapacity, or residual disability caused by irreversible pathological alterations, demand, and rehabilitation, and follow-up, over a long time and may present periods of improvement or visa vera in acute stages Barros et.al., 2006[4]. Most of the chronic diseases are life-threatening but can adopt the conventional approaches of care and management since it has a chronic course WHO, 2004[13]. Human beings suffer from communicable and non- communicable diseases.

Kidneys are vital organs whose basic function is to remove the waste products from the blood, which cleanses harmful toxins and ultimately convert the waste products into urine, which then flows to the urinary bladder where it is eventually discharged via the urethra. In the first step of making urine, the plasma is separated. The glomerulus called microscopic filter present in each nephron in kidney continuously filters the blood. The walls of the glomerulus permit smaller size molecules, wastes, and fluid (mostly water) to excrete into the tubule. Bigger molecules, such as proteins and blood cells, reside in the blood vessel Webster et.al[3],

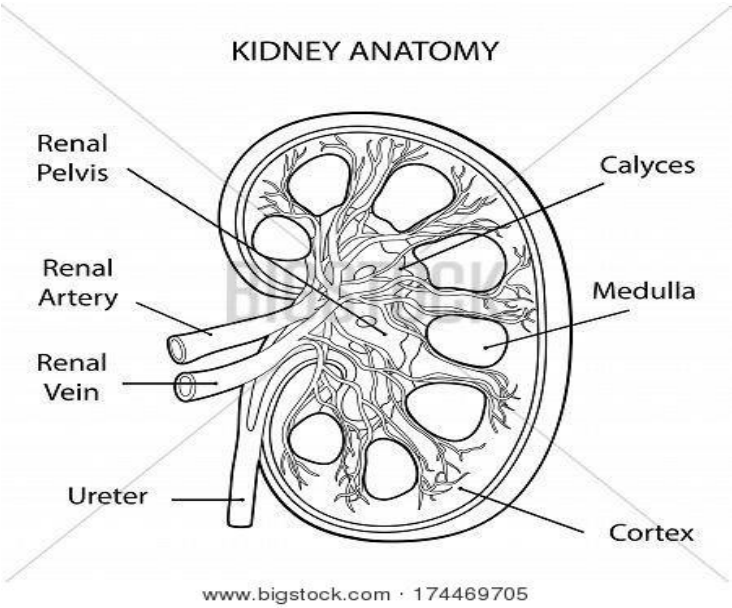

Figure: 1- Kidney Anatomy

Symptoms of CKD as follow:

- Lack of appetite
- Skin becomes itchy and dry
- Frequent need to urinate especially at night
- Muscle cramp during the night
- Unable to sleep at night
- Eyes look puffy especially in the morning
- Lack of energy and fatigue
- Unable to concentrate on a task
- Feet and ankles become swollen

Chronic Kidney Disease is one of the emerging major Noncommunicable Diseases, getting more attention of researchers and the medical community. In many cases, it leads to early death and disability. These diseases were considered to be affecting mostly the elderly and the wealthy, thus terming it to be a disease of affluence, affecting only those who are wealthy and the old. This belief prevented the timely intervention of strategies among patients who live in lower-income WHO, 2007[14]. Chronic Kidney Disease (CKD) carries high morbidity and mortality, as many patients live life through a frightening diagnosis.

According to WHO global health estimates, 864 226 deaths (or 1·5% of deaths worldwide) were attributable to this condition in 2012. Ranked fourteenth in the list of leading causes of death, CKD accounted for 12·2 deaths per 100 000 people. Since 1990, only deaths from complications of HIV infection have increased at a faster rate than deaths from CKD. Projections from the Global Health Observatory suggest that although the death rate from HIV will decrease in the next 15 years, the death rate from CKD will continue to increase to reach 14 per 100 000 people by 2030.[16]

Burr (1942)[2]suggested twelve different forms of the cumulative distribution functions of Burr distribution. Among those twelve distribution functions, Burr type X and Burr type XII have received the maximum attention.The Burr-XII distribution, which was originally derived by Burr (1942)[2] and received more attention by the researchers due to its broad applications in different fields including the area of reliability, failure time modeling and acceptance sampling plan. Reader can find the applications in various fields from Ali and Jaheen 2002[7] and Burr (1942).Abdel-Ghaly et.al., (1997)[1] applied the Burr type XII distribution to measure software reliability. Zimmer et.al., (1998)[18] also studied statistical and probabilistic properties of the Burr type XII distribution and described its relationship to other distributions used in reliability analyses. Moore and Papadopoulos (2000)[11]derived Bayesian estimators of the parameter and the reliability function for the Burr type XII distribution under three different loss functions. Ali Mousa and Jaheen (2002)[2] considered Bayesian estimation of the parameters of the Burr distribution based on progressively censored samples. Wu and Yu (2005)[17] proposed pivotal quantities to test the shape parameter and establish confidence interval of the shape parameter of the Burr type XII distribution under the failurecensored plan.Li et.al., (2007)[10] proposed the empirical estimators of reliability performances for Burr XII distribution under LINEX loss function.

BACKGROUND OF THE STUDY

Chronic kidney disease (CKD) is becoming a major public health problem worldwide. The current burden of disease is due to pathogenic progression of kidney disease. Patients with chronic kidney disease are at high risk for progression to the end stage renal disease (ESRD) – a condition in which kidney is no longer adequate to sustain life and renal replacement therapy requiring dialysis or kidney transplantation to maintain patient's long-term survival is required. The huge cost of treatment leads to a large burden for these patients and health care system, particularly in developing countries. Progress to kidney failure or other adverse outcomes could be prevented or delayed through early detection and treatment of chronic kidney disease[5].

Chronic kidney disease (CKD) as a progressive, irreversible deterioration in renal function in which the body's ability to maintain metabolic, fluid and electrolyte balance fails, resulting in uremia or azotemia which disturbs the homeostasis of all systems of the body. It can progress to end-stage renal disease (Stage -5 CDK) in which glomerular filtration rate (GFR) falls to 15 ml/minute/1.73 m^2 (Normal GFR=125 ml/minute/1.73 m^2)[8].

In India, there is a rising burden of chronic diseases like hypertension and diabetes mellitus. India has the largest number of diabetics in the world with a prevalence of 3.8% in rural and 11.8% in urban adults. The prevalence of hypertension has been reported to range between 20-40% in urban adults and 12-17% among rural adults. It is estimated that 25-40% of these patients are likely to develop chronic kidney disease with a significant percentage requiring renal replacement therapy. Prevalence of chronic kidney disease is associated with a large increase in cardio-vascular disease (CVD) risk. The cardio-vascular disease risk increases proportionally as estimated glomerular filtration rate (eGFR) falls below 60 ml/minute/1.73m^2 , lastly death from cardiovascular disease is eight-fold higher in chronic kidney disease, much higher than death from cancer. For non-communicable diseases like diabetes mellitus, hypertension and chronic kidney disease , the focus has been on developing advanced treatment facilities at the tertiary level.[9]

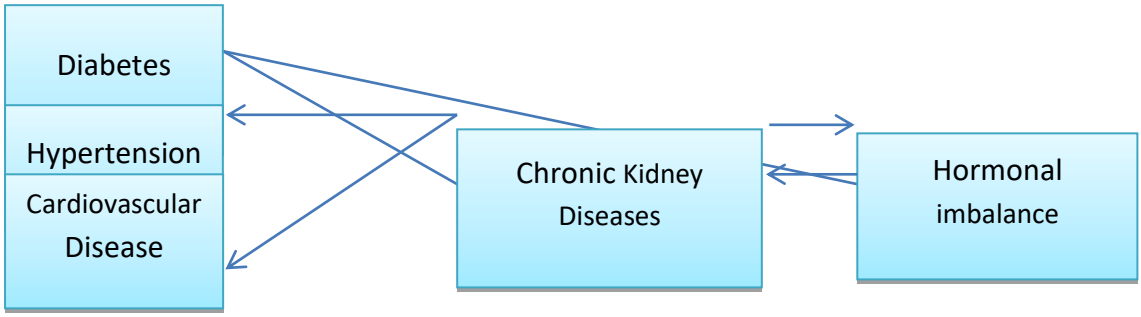

Figure: 2- Prognosis of persistent CKDS

MODEL DESCRIPTION AND SOLUTIONS

It is proposed herein that the extended three-parameter Burr XII distribution be defined by the cumulative distribution function Quanxi Shao et.al., (2004)[12].

$$F_{EBXII}(x;c,k,\lambda) = 1 - \left\{1 - k\left(\frac{x}{\lambda}\right)^{c}\right\}^{\frac{1}{k}} \quad k \neq 0$$

$$F_{EBXII}(x;c,k,\lambda) = 1 - e^{-\left(\frac{x}{\lambda}\right)^{c}} \quad k = 0 \qquad \ldots(1)$$

and the corresponding Probability Density Function (PDF) is

$$f_{EBXII}(x;c,k,\lambda) = c\lambda^{-1}\left(\frac{x}{\lambda}\right)^{c-1}\left\{1 - k\left(\frac{x}{\lambda}\right)^{c}\right\}^{\frac{1}{k}-1} \quad k \neq 0$$

$$f_{EBXII}(x;c,k,\lambda) = c\lambda^{-1}\left(\frac{x}{\lambda}\right)^{c-1} e^{-\left(\frac{x}{\lambda}\right)^{c}} \quad k = 0 \qquad \ldots(2)$$

The corresponding Survival Function is (SF)

$$\bar{H}(x) = e^{-\left(\frac{x}{\lambda}\right)^{c}} \ldots(3)$$

Now, assuming that the threshold Y follows an extended three parameter Burr XII distribution with parameter λ, it can be proved that

$$P(X_i < Y) = \int_0^{\infty} g_k(x) e^{-\left(\frac{x}{\lambda}\right)^{c}} dx = \left[g^*\left(\frac{1}{\lambda}\right)^{c}\right]^{k} \ldots(4)$$

$g_k(x)$ is the result of the Laplace Transformation of the convolution property and $\bar{H}(x)$Evaluate to efficacy of Chronic Kidney disease patients. The survival function $S(t)$ which is the probability that an individual's survives for a time t

$$P(T > t) = \sum_{k=0}^{\infty} V_k(t)\, P(X_i < Y)$$

It is also known from renewal theory that

$$= \sum_{k=0}^{\infty} [F_k(t) - F_{k+1}(t)] \left[g^* \left(\frac{1}{\lambda}\right)^c \right]^k \ldots (5)$$

Using convolution theorem for Laplace transforms, $F_k(t) = 1$and onsimplification, it can show that $L(T) = 1 - S(t)$ Taking Laplace Transformation of$L(T)$, we get

$$= 1 - \left\{ \sum_{k=0}^{\infty} [F_k(t) - F_{k+1}(t)] \left[g^* \left(\frac{1}{\lambda}\right)^c \right]^k \right\}^k \ldots (6)$$

On simplifications we get,

$$L(T) = \left[1 - g^* \left(\frac{1}{\lambda}\right)^c \right] \sum_{k=1}^{\infty} F_k(t) \left[g^* \left(\frac{1}{\lambda}\right)^c \right]^{k-1} \ldots (7)$$

Let the random variable U denoting inter arrival time which follows exponential distribution Laplace transforms with parameter v. Now,$f^*(s) = \left(\frac{v}{v+s}\right)$, substituting in the below equation we get,

$$l^*(s) = \frac{v\left[1 - g^* \left(\frac{1}{\lambda}\right)^c\right]}{\left[v + s - g^* \left(\frac{1}{\lambda}\right)^c v\right]} \ldots (8)$$

$g^*(.) \sim Exponential\ distribution\ with\ laplace\ Tranformation \quad \therefore \frac{\mu}{\mu + \lambda} \Rightarrow \lambda = \left(\frac{1}{\lambda}\right)^c$

$$= \frac{1}{v\left[1 - \frac{\mu}{\mu + \left(\frac{1}{\lambda}\right)^c}\right]} on\ simplification\ we\ get$$

$$E(T) = \frac{\mu + \left(\frac{1}{\lambda}\right)^c}{v\left(\frac{1}{\lambda}\right)^c} \qquad \ldots (\mathbf{9})$$

NUMERICAL ILLUSTRATION

The influence of parameters on the performance measures namely the expected time to Chronic kidney disease are studied numerically. In the following table these performance measures are calculated by varying the parameters one at a time and keeping the parameters and fixed$\mu, \lambda\ and\ C$.

Figure-3: Expected times of parameter μ increases at different level in chronic kidney disease patients.

Figure-4: Expected times of parameter λ increases at different level in chronic kidney disease patients.

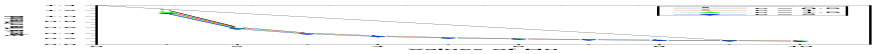

Figure-5: Expected times of parameter C increases at different level in chronic kidney disease patients

CONCLUSIONS

Burr distribution was originally known as Burr Type XII distribution which was one of the twelve types of the continuous distributions in Burr system. It has two shape parameters k and c, which implies that its probability density function and hazard rate function can be either decreasing or non-monotone. It is implied from the probability density function which can be either decreasing or unimodal, and the hazard rate function which can be either decreasing or upside-down bathtub shaped.This non-monotone hazard rate function has an important role in survival analysis. On the other hands, Burr distribution has a certain moment only because of its tail behavior. It has a tail index like Pareto distribution. This fact implies that Burr distribution is heavy-tailed.

When μ is kept fixed the inter-arrival time $'\nu'$ which follows exponential distribution, is an increasing case by the process of time to Chronic kidney disease. Therefore, Evaluate to Efficacy time $E(T)$ to cross the time to chronic kidney disease is found to be decreasing, in all the cases of the parameter value $\mu = 1,1.5,2,2.5,3$. When the value of the parameter μ increases, the Evaluate to Efficacy time is also found decreasing, this is observed in Figure 3.

When λ is kept fixed and the inter-arrival time $'\nu'$ increases, the value of the Evaluate to Efficacytime $E(T)$ to cross the time to Chronic kidney disease is found to be decreasing, in all the cases of the parameter value$\lambda = 1,1.5,2,2.5,3$. When the value of the parameter λ increases, the Evaluate to Efficacy time is found increasing, this is indicated in Figure 4.

When c is kept fixed and the inter-arrival time $'\nu'$ increases, the value of the Evaluate to Efficacy time $E(T)$ to cross the time to Chronic kidney disease is found to be decreasing, in all the cases of the parameter value$c = 1,1.5,2,2.5,3$. When the value of the parameter c increases, the Evaluate to Efficacy time is found increasing, this is indicated in Figure 5.

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