A DETAILED RISK ANALYSIS OF FACTORS CONTRIBUTING TO OCCURRENCE OF SUBDURAL HEMATOMA

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Abstract
The main objective of this research is to predict the occurrence of subdural hematoma which is connected to occurrence of stroke. The occurrence of stroke in turn can be predicted by calculating the associated risk factors in individuals based on the method developed by Putcha, et al. (2009). The variables considered in this study are: Age (AGE), Diastolic Blood Pressure (BPD), Systolic Blood Pressure (BPS),Total Cholesterol Level (TCL), HDL, Fasting Glucose (FBS), Creatinine (CRE), Triglycerides (TG) and Blood Urea Nitrogen (BUN) using the principles of probability, statistics and risk analysis for limited patient data that was available at the time of completion of this research paper.

Keywords: Risk Analysis, Hematoma, Probability, Statistics, Mean value, Standard Deviation, Risk factors

Introduction

As is well known, subdural hematoma is a collection of blood outside the brain, not in the brain itself. The blood collects between the dura and the next layer, the arachnoid. As blood accumulates, however, pressure in the brain increases. The pressure on the brain causes a subdural hematoma’s symptoms (lose consciousness and enter coma immediately depending on the rate of bleeding).Subdural hematoma can be caused by a head injury or stroke. This is because stroke itself can be a hemorrhage or blood clotting in cerebral vessels of all sizes.Hence, one way to predict the occurrence of subdural hematoma by predicting the occurrence of stroke. This approach is used in this paper.

The occurrence of strokecan be predicted using the Stroke Index (SI) .The stroke index can be considered like a Risk Factor is directly proportional to some of the parameters(AGE, BPD, TCL, FBS, CRE, TG and BUN) and it is inversely proportional to HDL. Hence, an equation for SI can be expressed as a product of these parameters using the corresponding constants of proportionality as:

*SI=k1*K2*k3*k4*k5*k6*k7*k8*AGE*BPD*TCL*FSB*CRE*TG*BUN/HDL (1)*

Where k1 to k8 are constants of proportionality. Since there is no actual data for SI, an alternative way of predicting SI is through Cumulative Risk Factors (CRF). CRF is a function of risk factors for AGE (RFAGE), Risk Factor for Diastolic Blood Pressure (RFBPD), Risk, Risk Factor for Total Cholesterol (RFTCL), Risk Factor for HDL (RFHDL), Risk Factor for Fasting Glucose (RFBS), Risk Factor for Creatinine (RFCRE), Risk Factor for Triglycerides (RFTG) and Risk Factor for Blood Urea Nitrogen (RFBUN) and this mathematical equation is given as:

CRF=RFAGE*RFBPD*RFTCL*RFBS*RFCRE*RFTG*RFBUN/RFHDL (2)

In previous study done by Putcha, et al. (2009) the following equationwas used:

CRF=RFTCL*RFLDL*RFBS*RFAGE/RFHDL (2a)

Eq. (2) is an improved model than Eq. (2a) as it incorporates more variables into the mathematical equation.

And for each of risk factors variableswe use in Eq. (2), relationslike:

RFAGE=AGEa/AGEn (2b)
RFBPD=BPDa/BPDn (2c)
RFTCL=TCLa/TCLn (2d)
RFHDL=HDLa/HDLn (2e)
RFBS=FBSa/FBSn (2f)
RFCRE=CREa/CREn (2g)
RFTG=TGa/TGn (2h)
RFBUN=BUNa/BUNn (2i)

And for RFLDL in Eq. (2a) we have, RFLDL=LDLa/LDLn (2j)

In the above equations, “a” stands for actual and “n” stands for nominal.

Methodology used for the present study

The rather simple equations - Eq. 1 and Eq. 2 shown above are based on the basic Resistance R and strength (S) model which is predominantly used in Reliability Analysis. The basic principle is that the probability of failure (P_f) is defined as:

$P_f = P(R < S)$ (3)

Where R = Resistance

S = load

Both R and S as random variables (mostly Gaussian), with the parameters μ_R (Mean value of Resistance) and σ_R(Standard Deviation of Resistance), μ_S (Mean value of load) andσ_S(Standard deviation of load). In the formulation of the medical problem discussed in here, all the actual values will be considered the parameter S while the allowable values (nominal values) will be considered under R.

Hence, the probability of failure $P_{f\ is}$ the intersection of the two regions represented by R and S.

In the formulation of the medical problem discussed in here, all the actual values will be considered in the cumulative parameter S while the allowable values (nominal values) will be considered under the cumulative parameter R.

General Details of Reliability and Risk Methodology (basis of present study)

Reliability and Risk Analysis is closely associated with uncertainties in various parameters connected with a structure. This is because almost all the variables associated with physical parameters are random in nature. The parameters associated with loads, and the load carrying capacities of structural members are all probabilistic quantities. These quantities have a certain distribution which can be obtained from the data in the literature or from experiments.

Some basic definitions of Reliability and Risk are given before application of these concepts to various disciplines are discussed.

Reliability of an element can be defined as (Haugen, 1980),

$R = P(S>L)$ (4)

Where, R = Reliability of the element

S = strength of the element

L = load on the element

The Risk is defined as (Ayyub et al., 1997),

Risk = Occurrence probability x occurrence consequence (5)

The seminal reliability work has been performed by various authors [3, 4]. In the research work reported therein, the load and resistance variables are assumed to be random variables. The necessary statistical information about these variables is supposed to be known including the distributions that these variables follow.

For reliability analysis, the definition of limit state is essential [Ellingwood et al., 1980; Nowak and Collins, 2000)

This relation is given by,

$g(x_1, x_2, \ldots, x_n) = 0$ (6)

where, x_i = resistance or load variable.

The failure is supposed to occur when $g<0$ for any ultimate or serviceability limit state of interest. Failure for any limit state does not automatically imply collapse or other catastrophic events. The safety is assured by assigning a small probability of failure p to the event connected with the limit state. This can be expressed as,

$p_f = \int \ldots\ldots \int f(x_1, x_2, \ldots, x_n)\, dx_1\, dx_2 \ldots dx_n$ (7)

First Order Second Moment Methods (FOSM):

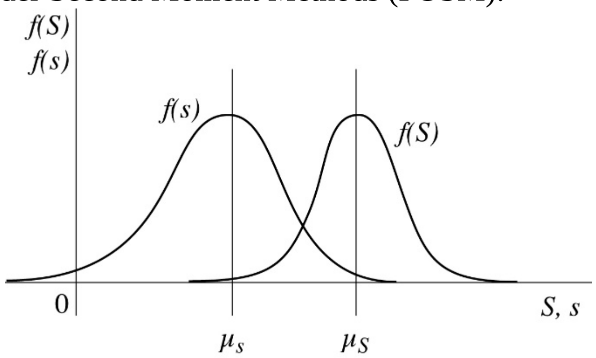

Fig. 1 Stress-Strength density functions

The p_f is in effect the intersection of the Warren diagram shown in Fig. 1.

Detailed steps used in the present study

The methodology followed to calculate the cumulative risk factors is given below:

1. Obtain the actual values of all the variables from the actual patients in this medical study. These are listed below:
   - Age (AGE)
   - Diastolic blood Pressure (BPD)
   - Total Cholesterol level (TCL)
   - High-Density Lipoprotein (HDL)
   - Low-density lipoprotein (LDL)
   - Fasting Blood Sugar (FBS)
   - Creatinine (CRE)
   - Triglycerides (TG)
   - Blood Urea Nitrogen (BUN)
2. Obtain the nominal values of the above variables from literature.

3. Calculate various Risk Factors associated with each of the above variable: RFAGE, RFBPD, RFTCL, RFHDL,RFBS, RFCRE, RFTG and RFBUN fromEq. 2b-2j.
4. The CRF for the set of data is then obtained using Eq. 2. It is decided to use Eq. 2 instead of calculating SI from Eq. 1. This is because, using Eq. 1 essentially involves calculation of probability of failure using multiple integral denoted by Eq.7 which is a cumbersome process especially with this many variables in the present study.

Input data

Two case studies were examined for this research. The input data used for the actual and nominal values for various variables in the present study for case studies are given in Table 1 for case study 1 andin Table 2 through Table 8 for case study 2 for various combinations of μ and σ. Here μ represents the mean value and σ represents standard deviation of the random variable under consideration.
below.

Table 1 Actual and nominal values for the input variables for case study 1

Variable value	Actual value	Nominal
AGE	60	50
TCL	170	200
HDL	40	42
LDL	109	100
FBS	99	90
BPD	150	120

Table 2 Actual and nominal values for the input random variables (μ) for case study 2

Variable value	Actual value (μ)	Nominal
AGE	34.2	50
BPD	83	80
TCL	163.4	200
HDL	66.3	45
FBS	93.4	100
CRE	0.184	1.0
TG	110.1	150
BUN	20.2	43

Table 3 Actual and nominal values for the input random variables(μ-σ)for case study 2

Variable value	Actual value (μ-σ)	Nominal
AGE	23.65	50
BPD	73.94	80
TCL	120.19	200
HDL	51.41	45
FBS	73.22	100

CRE	0.63	1.0
TG	77.16	150
BUN	14.89	43

Table 4 Actual and nominal values for the input random variables(μ-+σ)for case study 2

Variable	**Actual value (μ+σ)**	**Nominal value**
AGE	44.75	50
BPD	92.06	80
TCL	206.61	200
HDL	81.19	45
FBS	113.58	100
CRE	0.99	1.0
TG	143.04	150
BUN	25.51	43

Table 5 Actual and nominal values for the input random variables(μ-2σ)for case study 2

Variable	**Actual value (μ-2σ)**	**Nominal value**
AGE	13.09	50
BPD	64.89	80
TCL	76.99	200
HDL	36.51	45
FBS	53.05	100
CRE	0.45	1.0
TG	44.21	150
BUN	9.59	43

Table 6 Actual and nominal values for the input random variables(μ+2σ)for case study 2

Variable	**Actual value (μ+2σ)**	**Nominal value**
AGE	55.31	50
BPD	101.11	80
TCL	249.81	200
HDL	96.09	45
FBS	133.75	100
CRE	1.18	1.0
TG	175.99	150
BUN	30.81	43

Table 7 Actual and nominal values for the input random variables(μ-3σ)for case study 2

Variable	**Actual value (μ-3σ)**	**Nominal value**
AGE	2.54	50
BPD	55.83	80
TCL	33.78	200
HDL	21.62	45
FBS	32.87	100
CRE	0.27	1.0
TG	11.27	150

BUN	4.28	43

Table 8 Actual and nominal values for the input random variables($\mu+3\sigma$)for case study 2

Variable	**Actual value ($\mu+3\sigma$)**	**Nominal value**
AGE	65.86	50
BPD	110.17	80
TCL	293.02	200
HDL	110.98	45
FBS	153.93	100
CRE	1.36	1.0
TG	208.93	150
BUN	36.12	43

Results

Using the detailed steps described in Section 4 above, the Risk factors for various variables used are calculated and they are shown for Case study 1 in Table 9 and in Tables 10-16 for Case study 2 as shown below.

Table 9 Risk factors (RF) for various variables in case study 1

Variable	**Risk factors (RF)**
AGE	1.2
TCL	0.85
HDL	0.95
LDL	1.09
FBS	1.1

The cumulative risk factor (CRF) from Eq. 2a for Case study 1 is 1.28

Table 10 Risk factors (RF) for various variables in case study 2 (data from Table 2)

Variable	**Risk factors (RF) for μ**
AGE	0.68
BPD	1.03
TCL	0.82
HDL	1.47
FBS	0.93
CRE	0.184
TG	0.73
BUN	0.47

The cumulative risk factor (CRF) from Eq. 2 for Case study 2 is 0.05.

Table 11 Risk factors (RF) for various variables in case study 2 (data from Table 3)

Variable	**Risk factors (RF) for $\mu-\sigma$**
AGE	0.47
BPD	0.924
TCL	0.6
HDL	1.14
FBS	0.73
CRE	0.63
TG	0.51
BUN	0.35

The cumulative risk factor (CRF) from Eq. 2 for Case study 2 is 0.02

Table 12 Risk factors (RF) for various variables in case study 2 (data from Table 4)

Variable	**Risk factors (RF) for μ+σ**
AGE	0.895
BPD	1.15
TCL	1.03
HDL	1.8
FBS	1.135
CRE	0.99
TG	0.953
BUN	0.593

The cumulative risk factor (CRF) from Eq. 2 for Case study 2 is 1.22

Table 13 Risk factors (RF) for various variables in case study 2 (data from Table 5)

Variable	**Risk factors (RF) for μ-2σ**
AGE	0.26
BPD	0.81
TCL	0.384
HDL	0.81
FBS	0.53
CRE	0.45
TG	0.294
BUN	0.223

The cumulative risk factor (CRF) from Eq. 2 for Case study 2 is 0.001

Table 14 Risk factors (RF) for various variables in case study 2 (data from Table 6)

Variable	**Risk factors (RF) for μ+2σ**
AGE	1.11
BPD	1.26
TCL	1.249
HDL	2.135
FBS	1.33
CRE	1.18
TG	1.173
BUN	0.716

The cumulative risk factor (CRF) from Eq. 2 for Case study 2 is 4.947

Table 15 Risk factors (RF) for various variables in case study 2 (data from Table 7)

Variable	**Risk factors (RF) for μ-3σ**
AGE	0.05
BPD	0.697
TCL	0.168
HDL	0.48
FBS	0.32
CRE	0.27
TG	0.075
BUN	0.099

The cumulative risk factor (CRF) from Eq. 2 for Case study 2 is 0

Table 16 Risk factors (RF) for various variables in case study 2 (data from Table 8)

Variable	**Risk factors (RF) for μ+3σ**
AGE	1.317
BPD	1.377
TCL	1.465
HDL	2.466
FBS	1.53
CRE	1.36
TG	1.392
BUN	0.84

The cumulative risk factor (CRF) from Eq. 2 for Case study 2 is 16.053

The results shown for risk factors in Table 9for case study 1 are considering the values of the variables at the mean **μ.** On the other hand, the results for Case 2 in Tables 9-16 showrisk factors for ranges of (**μ-σ** to **μ+3σ**) of the probabilistic variables used in the study. This is because the range from **μ-σ to μ+σ** encompasses the uncertainty of around 68.3%, **μ-2σ to μ+2σ** encompasses the uncertainty of around 95.4%,and **μ-3σ to μ + 3σ**encompasses the uncertainty of around 99.7% (Ang and Tang, 1975).

Discussion of Results and Conclusions

The results for case study 1 shown in Table 9 indicate that the CRF is 1.28 which is less than the acceptable value of 2.0 implying no stroke. The value of 2 is chosen because a normalized value of 2 encompasses an uncertainty of 95.5% which is acceptable for all practical problems. The results shown for case study 2 range from 0 t0 16.053 for the extreme limits of μ-3σ to μ + 3σ. For the practical normalized range μ-2σ to μ + 2σ, the CRF ranges from 0 to 4.94 giving an average of 2.47 which indicates the possibility of stroke.

Conclusion

A simple mathematical equation has been developed based on the basic concepts of Reliability and Risk Analysis. Two case studies were discussed. While one case study indicates no stroke, the other case study indicates possibility of stroke. More study is required with a larger set of data to fine tune the equation developed but it is a good start.

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