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Internal Validation of a Subjective Bayesian Model for the Prediction of Anesthetic Accidents in Hospitals in Kinshasa

Berthe Nsimire Barhayiga[1], Gibency Mpenda Mfulani[1], Konde[2], Rostin Matendo Mabela[3], Adolphe Manzanza Kilembe[1], Sylvain Mukongo Munyanga[2], Christian Kisoka Lusunsi[5], Benjamin Longo-Mbenza[4, 5, *]

[1]Department of Anesthesia-Resuscitation, University Clinics of Kinshasa, Kinshasa, Democratic Republic of Congo
[2]School of Public Health, Faculty of Medicine, University of Kinshasa, Kinshasa, Democratic Republic of Congo
[3]Department of Mathematics, Faculty of Sciences, University of Kinshasa, Kinshasa, Democratic Republic of Congo
[4]Cardiology Service, Department of Internal Medicine, University Clinics of Kinshasa, Kinshasa, Democratic Republic of Congo
[5]Department of Public Health, Lomo University for Research, Kinshasa, Democratic Republic of Congo

Email address:

berthebarhayiga@gmail.com (B. N. Barhayiga), berthe.barh ayiga@unikin.ac.cd (B. N. Barhayiga), gibencymfulani1990@gmail.com (G. M. Mfulani), nnkonde@gmail.com (Konde), rostin.mabela@unikin.ac.cd (R. M. Mabela), mabelamatendorostin@gmail.com (R. M. Mabela), yaadolphekilembe@gmail.com (A. M. Kilembe), munyagam@yahoo.fr (S. M. Munyanga), christiankisoka1@gmail.com (C. K. Lusunsi), longombenza@gmail.com (B. Longo-Mbenza), longo.mbenza@unikin.ac.cd (B. Longo-Mbenza)

[*]Corresponding author

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Abstract: *Background and Aims:* This study evaluates the Subjective Bayes Model (SBM) by comparing it to the consensus of the 75 hypothetical cases having experienced an anesthetic accident, generated by the Experts. *Methods:* The experts generate the cases with anaesthetic accidents and determine the degrees of agreement within and between experts, the discrimination criterion called Cut Off Point (C.O.P.), and look for the values of the following parameters: sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV), overall effectiveness value (VEG). *Results:* The laboration of the 75 hypothetical cases of anaesthetic accidents by the experts. The intra and inter expert agreement was 100% perfect reflecting the consistency of the experts. The MSB predicts the occurrence of AA in 37 cases and the non-occurrence of AA in 27 cases confirmed by the consensus of the experts: the discrimination criterion (Cut of point = COP) is equal to 0.5, the MSB presents a good intrinsic validity with test performances of Se = 94. 8%, Sp = 75%, VP = 80%, NPV = 93% and VEG = 85%, the MSB gave an 80% probability that an AA identified as having occurred would actually occur (PPV) and a 93% probability that an AA identified as not having occurred would not occur (NPV). *Conclusion:* Expert consensus on the occurrence of SAs in the 75 hypothetical cases of anaesthetic accidents generated by the Experts was used to determine the internal validation of the Subjective Bayes Model of anaesthetic accident prediction.

Keywords: Anaesthetic Accident (AA), Internal Validation, Subjective Bayes Model

1. Introduction

Anaesthesia can be described as the pharmacological suppression of the majority of the body's physiological control mechanisms i.e. a complete blockade of pain and consciousness and modulation of the neuromuscular, cardiovascular and respiratory systems [1]. Ideally, an anaesthetic drug should be potent, specific, with a rapid onset of action and an absence of side effects. Despite the development of new molecules, this ideal is still far from being achieved [2].

Risk management is shared between the different members of the team [3]. Time management appears to be an essential element in the control of the situation both in terms of the synchronisation of the anaesthetist's activity and in terms of anticipation and its application. Indeed, the anaesthetist often works in an anticipatory mode in order to prevent possible drifts but cannot anticipate everything [4].

The planning carried out is then a short-term planning and many adjustments are necessary to allow the anaesthetist to keep control [5]. The study of the recovery from drifts shows that this is ensured by the use of protocols and guidelines recommended by the speciality, but also by a certain "allostasis of risk" [6]. The impact of anticipation on risk management is controversial as it may both allow for better management but may also mislead the anaesthetist when he/she believes that the anticipation carried out has normally prevented the problem. Finally, [5] differences in the organisation of the process show that anaesthetists manage the process either by prevention or by real-time management [5].

The occurrence of an AA is a dramatic event. Although the frequency of deaths directly attributable to anaesthesia seems to have decreased [6]. Complications, whether serious or not, remain frequent, placing anaesthesia among the high-risk specialities [7]. Moreover, regulatory measures have been put in place to improve the safety of the anaesthetic process and to sensitise and encourage anaesthetists to analyse their complications to control this risk.

This study was conducted to assess the validity of the MSB for predicting AA from the cases generated by the panel of fifteen experts selected from eight hospitals. Its purpose was to facilitate clinicians' use of a previously developed Bayes Mathematical Model with 8 predictive factors for AA, all of which were modifiable. These were: the presence of an unfavourable state of health, the presence of drugs with adverse effects, the presence of unqualified and incompetent anaesthetists, the inadequacy of the anaesthetic procedure, the complexity of the surgical procedure and the incompetence of the surgeon, the absence and/or inadequacy of materials, the emergency procedure and the inadequacy of organisation.

In developing countries, various provisions are implemented for the prevention of AA. However, in sub-Saharan Africa, and mainly in DR Congo, no study on the prevention of AA has been initiated. This is why, faced with an ever-increasing number of AA [6, 7, 10, 12], we undertook the present study, the aim of which was to contribute to reducing the frequency of AA in our environment.

The objective was to assess the validity of the subjective Bayesian model by comparing it with the hypothetical cases generated by the various experts who were used to develop it.

2. Material and Methods

This This study used the qualitative method in the form of a nominal group, again based on Bayesian statistics and adapted from the work of Gustafson [8, 9].

The internal validation of the SBM is the performance of the test against a reference method. The Subjective Bayes Model (SBM) was validated in three steps:

1. determination of the degree of intra- and inter-expert agreement for the AA prediction model.
2. determination of the discrimination criterion or cut-off point (COP) for the AA prediction model.
3. validation of the model itself.

To determine the degree of intra- and inter-expert agreement, each of the experts constructed five hypothetical cases of AA, with the presence of one or other factor contributing to the occurrence of AA. And in plenary, they determined the probability of the occurrence of AA on two occasions and individually; the Intra and Inter Experts agreement degrees taken two by two using the Kappa statistic, obtained by the following formula:

$$K = \frac{P_0 - P_e}{1 - P_e}$$

Where Pe= expected or expected match probability;
Po= observed probability of agreement;
K= value between 0 and 1;
If K<0.4: low approval;
0.4≤K 0.6: approval is average;
0.6≤K<0.8: approval is good;
K≥0.8: approval is excellent.

The determination of the discrimination criterion (COP) was made by calculating these parameters for each value between 0.1 and 0.9 and between the two bounds of this interval, the Cut off point (COP) was determined, which corresponded to the value where the Subjective Bayes Model (SBM) had the highest sensitivity and specificity. Only when the COP was selected was the model used to classify cases into AA and non-AA.

The actual validation consisted of evaluating the performance of the model, the results of the MSB were compared with the hypothetical cases produced by the experts on which they had obtained a consensus of accident or no accident. The construction of a contingency table allowed the calculation of the parameters: sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV) and overall effectiveness value (VEG).

3. Results

3.1. Determination of the Degree of Intra-Expert Approval

The degree of intra-expert approval (of each expert with himself) was determined by calculating the KAPPA statistic. Each expert had generated five [5] hypothetical cases for which he had predicted in the first and then in the second round the probability of experiencing an AA. The 2X2 contingency tables were constructed for this purpose with a positivity threshold of MSB 0.5 (Cfr. Table 1).

All intra-expert Kappa's were above 0.75. The intra-expert agreement was therefore excellent (perfect).

Intra-expert agreement was 100% perfect, reflecting the degree of self-consistency of the expert. These results show a very high degree of consistency in the experts reasoning.

Table 1. *Intra Expert approval.*

		FIRST ROUND														
		EXP1	**EXP2**	**EXP3**	**EXP4**	**EXP5**	**EXP6**	**EXP7**	**EXP8**	**EXP9**	**EXP10**	**EXP11**	**EXP12**	**EXP13**	**EXP14**	**EXP15**
Second Turn	EXP1	1														
	EXP2		0.97													
	EXP3			0.92												
	EXP4				0.88											
	EXP5					0.91										
	EXP6						1									
	EXP7							0.97								
	EXP8								0.97							
	EXP9									0.95						
	EXP10										0.97					
	EXP11											0.93				
	EXP12												0.85			
	EXP13													1		
	EXP14														0.92	
	EXP15															0.97

3.2. Determination of the Degree of Inter-Expert Approval

For inter-expert agreement, the five hypothetical cases of AA generated and predicted by each expert were predicted by another expert according to the combinations in Table 2. The calculations were carried out using the 2X2 contingency tables constructed for this purpose. The SBM 0.5 was set as the threshold for positivity. Thus, the KAPPA statistics were calculated to determine the degree of inter-expert agreement. The calculations were carried out by using the 2X2 contingency tables constructed for this purpose. The MSB 0.5 had been set as the threshold for positivity. Thus the calculations of the KAPPA statistics had made it possible to determine the degree of inter-expert agreement.

Table 2. *Inter Expert Approval.*

KAPPA	**EXP1**	**EXP2**	**EXP3**	**EXP4**	**EXP5**	**EXP6**	**EXP7**	**EXP8**	**EXP9**	**EXP10**	**EXP11**	**EXP12**	**EXP13**	**EXP14**	**EXP15**
EXP1															
EXP2	0.80														
EXP3	0.72	0.76													
EXP4	0.78	0.78	0.65												
EXP5	0.77	0.72	0.59	0.80											
EXP6	0.79	0.79	0.61	0.82	0.80										
EXP7	0.66	0.82	0.73	0.65	0.59	0.61									
EXP8	0.66	0.82	0.79	0.65	0.59	0.61	0.89								
EXP9	0.80	0.90	0.76	0.83	0.76	0.79	0.76	0.76							
EXP10	0.75	0.79	0.71	0.78	0.76	0.74	0.71	0.71	0.71						
EXP11	0.76	0.81	0.63	0.84	0.78	0.89	0.63	0.63	0.63	0.76					
EXP12	0.72	0.77	0.58	0.71	0.65	0.71	0.64	0.64	0.64	0.72	0.69				
EXP13	0.79	0.79	0.76	0.73	0.66	0.69	0.81	0.81	0.81	0.79	0.71	0.72			
EXP14	0.90	0.80	0.72	0.83	0.81	0.79	0.72	0.72	0.72	0.85	0.76	0.72	0.79		
EXP15	0.69	0.84	0.87	0.68	0.62	0.64	0.81	0.87	0.79	0.74	0.66	0.66	0.79	0.69	

The calculations showed that the inter-agreement was perfect or acceptable; indeed, out of the 105 inter-expert agreements, 54 (51%) were scored with a K >0.75 and 51 (49%) with a K < 0.75 acceptable.

There was a high degree of consistency (concordance) of reasoning between the experts (100%). This being the case, the group of experts could be considered homogeneous, i.e. as if it were one person, and justifies the height or degree of confidence that could be placed in the consensus of the experts' opinions. We could thus use the arithmetic mean of their probability estimates to assess the SBM.

3.3. Determination of the Discrimination Point or Cut off Point (COP)

This criterion is defined as the value between 0.1 and 0.9 at which the model has high sensitivity and specificity.

For each value between 0.1 and 0.9 the sensitivity, specificity, positive predictive value and negative predictive value as well as the overall effectiveness value were calculated for this study (see Table 3).

The highest values were: Se 94.8%; Sp 75%; PPV 80.4%; NVP 93.1% and MPV 85.3%. These values were obtained at the discrimination point of 0.5, which was the COF.

Table 3. *The COP of 75 AA cases according to the expert consensus (EC) MMB with 8 risk factors was constructed from the EC probabilities and SBM probabilities.*

	at	b	vs	d	S	SENSITIVITY	SPECIFICITY	VPP	vpn	VPG	Se+Sp
0.1	39	32	0	4	75	100%	11%	54.9%	100%	57.3%	111%
0.2	39	26	0	10	75	100.0%	27.8%	60.0%	100.0%	65.3%	128%
0.3	39	18	0	18	75	100.0%	50.0%	68.4%	100.0%	76.0%	150%
0.4	37	12	2	24	75	94.9%	66.7%	75.5%	92.3%	81.3%	162%
0.5	37	9	2	27	75	94.9%	75.0%	80.4%	93.1%	85.3%	170%
0.6	31	5	8	31	75	79.5%	86.1%	86.1%	79.5%	82.7%	166%
0.7	15	1	24	35	75	38.5%	97.2%	93.8%	59.3%	66.7%	136%
0.8	4	0	35	36	75	10.3%	100.0%	100.0%	50.7%	53.3%	110%
0.9	2	0	37	36	75	5.1%	100.0%	100.0%	49.3%	50.7%	105%

3.4. Internal Validation of the Subjective Bayes Model (SBM) Itself

Taking into account the values a, b, c, d, corresponding to the discrimination criterion given in Table 4, the performance of the SBM had been verified from the 2X2 contingency table (Confrontation). Indeed, the information of the experts' consensus had been given by the arithmetic mean of the probabilities of the hypothetical cases generated by the experts.

These different averages were compared at the 0.5 discrimination point to provide the elements of the contingency table below:

Table 4. *Internal validation expert consensus.*

		EC Expert Consensus (0.5)		Total
		AA+ exists	**AA- does not exist**	
SBM (0.5)	AA+ exists	37 (a) PV	9 (b) PF	46 = a1
	AA- does not exist	2 (c) FN	27 (d) NV	29 = b1
	Total	39 = a2	36 = b2	75

Legend: AA= Anesthetic accident at_1= VP+FP
PV= Pre valuesaying b1= FN+VN
FP= False Positive at_2= VP+FN
FN= False Negative b_2= FP+VN
VN= True Negative.

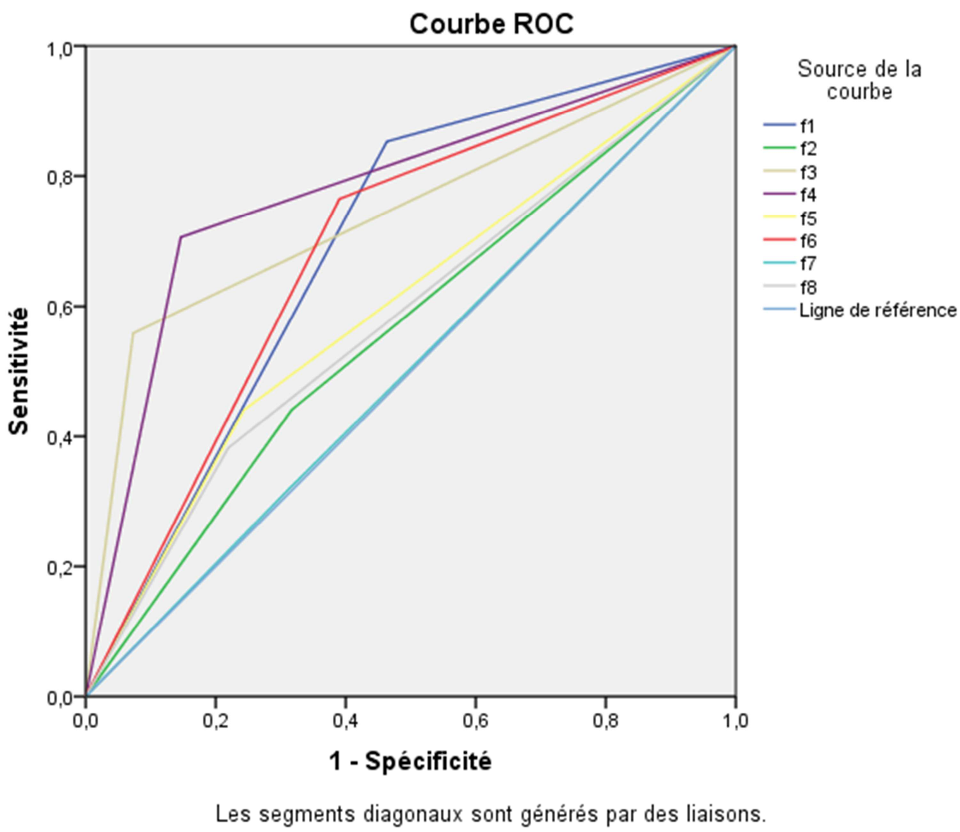

Figure 1. *ROC curve of MSB efficiency.*

The application of the SBM, with the values at the point of discrimination 0.5 compared to the consensus of the Experts had shown that the SBM predicted the occurrence of AA in 37 cases and the non-occurrence of AA in 27 cases confirmed by the consensus of Experts i.e. the model exhibited good intrinsic validity with test performance of Se = 94.8%, Sp = 75%, PPV = 80.4%, VPN = 93.1% and VEG = 85.3% as shown in Table 2.

When the various parameters calculated above were observed, the SBM gave a proportion of 49.3% of AAs correctly identified as having appeared (Se) and a proportion of 12% of AAs correctly identified as not having occurred (Sp).

In addition, the SBM had given an 80% probability that an AA identified as having appeared would actually occur (PPV) and a 93% probability that an AA identified as not having appeared could not occur (NPV).

Hence, the MSB was considered to perform well internally and its validity was established given that the calculated parameters were very high.

This performance could also be graphically illustrated by the ROC curve, which showed significant areas under the curve for the various factors analyzed, i.e. 0.78 respectively with 95% CI (0.67-0.89) for F4; 0.74 with 95% CI (0.63-0.86) for F3; 0.69 with 95% CI (0.57-0.81) for F1; 0.68 95% CI (0.56-0.80) for F6; 0.59 95% CI (0.46-0.72) for F5; 0.58 95% CI (0.45-71) for F8; 0.56 95% CI (0.43-0.69) for F2 and finally 0.50 95% CI (0.37-0.63) for F7.

Just as when calculating the Youden index, we could also see this efficiency of the test, which allowed us to say that the MSB was discriminating, i.e. it made it possible to distinguish between patients susceptible to experience an anesthetic accident and those who are not at risk.

For the 75 hypothetical cases, the Youden index: Se (0.95) + Sp (0.75) -1= 0.7 was greater than 0.50 this meant that the test was positive, that the method was perfect.

In the clinical situation, sensitivity (Se) and specificity (Sp) are most often used because the sensitivity for an event such as AA depends on the definition, the characteristics and the circumstances of occurrence of the event. In particular, it is not likely to vary from one hospital center to another. While the PPV and the NPV are functions of the respective proportions of the event and of the non-event in the population, the prevalence of the event is defined as $\frac{évènement}{non\ évenèment}$.

These predictive values vary from one hospital center to another for the same event, which explains why they are less used as evaluation parameters [13, 14].

4. Discussion

The occurrence of AA in the hypothetical cases generated by the selected experts in large hospitals in Kinshasa (DRC) was determined by the Subjective Bayes Model (SBM) combining eight factors which, in decreasing order of impact are according to RVs were then grouped into: F1= presence of unfavourable health status (RV= 2.4), F3 & F7 = presence of unqualified (non-competent) anaesthetists and emergency surgery (LHR = 1.9), F4 & F5 = inadequate anaesthetic practice and complexity of the surgical procedure and incompetence of the surgeon (LHR = 1. 4), F6 = absence and inadequacy of materials and equipment (LHR=1, 3), F8 = inadequate organisation (LHR=1,2) and F2= presence of drugs with adverse effects (LHR=0,8) [15, 16].

The LHR or RV likelihood ratio of 19.6 of the subjective Bayes model constructed showed that these factors had a significant positive impact on the occurrence of AA; the Qapri is 0.43, therefore less than 1, which showed that the patient was less likely to develop than not to develop AA. The Qapo was 8.96.

All the 8 risk factors for AA found in the literature had been retained by the SBM as having a positive impact on the occurrence of AA [17-19].

When all eight factors were present in a patient, the patient had a 90% probability of developing AA according to the SBM, which was a very high risk. If all seven factors were present, the probability was 90%, with six factors present, the probability was 80%, with five factors, the probability was 70%, with four factors, the probability was 60%, with three factors, the probability was 50%, with two factors, the probability was 40%, with one factor, the probability was 30%, with zero factors, the probability was 19%. This is in line with the conclusions of studies on the strength of association of factors for AA to occur, which state that there is no such thing as zero risk [11, 2, 6, 7].

Correct perioperative patient assessment and close monitoring have been shown to reduce the occurrence of AA to 0.5% in industrialised countries [20]. Prevention is a priority treatment to reduce the occurrence of AA because it allows early detection of modifiable factors of AA and effective intervention [2, 3, 7, 9].

5. Conclusion

The subjective Bayes model thus constructed showed good intrinsic validity with test performances of Se = 94.8%, Sp = 75%, VP = 80%, NPV = 93% and VEG = 85%; it gave an 80% probability that an AA identified as having occurred would actually occur (PPV) and a 93% probability that an AA identified as not having occurred would not occur (NPV).

Conflict of Interest

The authors declare that they have no competing interests.

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