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A Multi-criteria Approach for the Selection of "Best" Anesthetic Drug

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ABSTRACT: *The introduction of anesthesia in medical history has changed the definition of surgeries. Ever since its discovery in 1846, anestheologist have took it a long way. Out of three generally used anesthetic techniques, general anesthesia is the one which is given to the patient to produce amnesia and analgesia during surgery. It can be understood as the controlled, reversible state of unconsciousness. General anesthesia when given inappropriately can be dangerous to the life, thus proper management of anesthesia is necessary before any surgery. The choice of anesthesia depends on many factors since there doesn't exist any single anesthetic drug which fulfils the requirement of "best" drug for the purpose. To facilitate the selection process of best drug among the available ones, based on many factors, we present a multi-criteria approach in this paper.*
Keywords: *General anesthesia, multi-criteria, inhaled anesthetics, injected anesthetics*

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I. INTRODUCTION

Practice of surgeries existed long before the discovery of anesthesia but the notion of the painful surgeries was so petrifying that people used to choose disease over surgeries. So, one of the greatest discoveries in the history of medicine is the ability to alleviate pain and making modern surgical practices possible. Birth of modern anesthesia include the discussion of two gases: ether and chloroform (Robinson & Toledo, 2012). So, it was in 1846, William T.G. Morton used the ether anesthesia for surgery for the very first time at Massachusetts General Hospital. After the popularity of ether, chloroform, a more volatile general anesthesia came into existence overcoming the shortcomings of using ether. By the end of 19th century, anesthesia became the first example in which medical practice was backed by emerging scientific developments. Today with its evolution over time, anesthesia-related operative mortality occurs in a vanishingly small number of cases and significant anesthesia related mortality is rare.

With the advancement in modern anesthesiology, anesthesia now can be administered in four types. Depending upon the type and length of the surgery, patient's health and the preference of patient and surgeon, anesthesia can be administered either as local anesthesia, general anesthesia, regional anesthesia and monitored anesthetic care with conscious sedation. Different risks and benefits attached to various types of anesthesia is discussed with patient prior to the surgery. We have restricted this study only to general anesthesia. General anesthesia is a drug-induced reversible loss of consciousness which include specific behavioral and physiological traits- unconsciousness, amnesia, analgesia and akinesia- with concomitant stability of the autonomic, cardiovascular, respiratory and thermoregulatory systems. It interrupts nerve signals in patient's brain and body and prevent brain from processing pain and remembering what happened during surgery. General anesthesia can be induced in two forms: inhalational and intravenous (using injection). Many drugs are available to serve this purpose. There are different side-effects attached to the use of general anesthesia which can be seen after surgeries like nausea, vomiting, sore-throat, muscle aches, itching, mild-hoarness. None of the available drug in market comes without some future health consequences. So, there does not exist any single drug which can be considered as the ideal drug. It is the task of anesthesiologist to select the best drug before surgery which aims to minimize risks (morbidity and mortality) and side effects.In this study, we are considering any particular drug to be the "Best" drug on the basis of few parameters.

Selection of best drug depends on many parameters. It is the task of anesthesiologists to select the best drug before surgery. Since this act of decision making include several conflicting alternatives. This can be considered as the multi-criteria decision making problem and can be handled best with the help of multi-criteria decision making tools. Multi-criteria decision making (MCDM) has grown up as a part of Operations Research, concerned with designing computational and mathematical tools for supporting the subjective evaluation of performance criteria by decision makers.

The idea of using MCDM tools in medicine is not new to the literature. Sobrie et al.(2015) used a Majority Rule sorting model, a MCDA technique to select(accept or refuse) the patient for surgery. Carter et al.(1999) compared well known methods Analytical Hierarchy Process (AHP) and Analytic Network Process (ANP) with Markov process in order to get the optimal post-lumpectomy treatment surgery for a women with early stage breast cancer. Castro et al.(1996) also used AHP to select the best test for patient suffering from abdominal pain with goal to minimize risk, patient discomfort and cost of testing and maximizing diagnostic capability. Ali et al.(2018) used the Decision Making Trial and Evaluation Laboratory (DEMATEL) technique to identify the factors (medical and non-medical) to study the rise of cesarean section rate in Pakistan. Liu et al. (2015) used the Fuzzy-AHP and Fuzzy-VIKOR method to analyze the risk of general anesthetic method. La Scalia et al.(2011) used Fuzzy-TOPSIS for pancreatic islet transplantation. They identify the criteria and within fuzzy environment used Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to generate ranking between alternatives. Zhang et al.(2016) apply hesitant fuzzy linguistic VIKOR method to the inpatient admission assessment process. Hancerliogullari et al.(2017) used Fuzzy-AHP and Fuzzy-TOPSIS for the selection of best anesthetic method for circumcision surgery. Liberatore&Nydick (2008) review the application of AHP in medical and healthcare decision making.

For making our problem to comply more with the real world situation, fuzzy variables has been used. Fuzzy variables can deal with the vagueness, uncertainty and can take linguistic values rather than precise numerical values. Ever since its introduction by (Zadeh, 1965), fuzzy set theory has been used rigorously to handle uncertainty and vagueness in various industrial and management problems. Wu et al.(2004) adopted fuzzy set theory in SERVQUAL for determining the positioning of service quality in health-care and helps in prioritizing the different service strategies which in turn enables the managers to collate the service strategy of the benchmarking hospitals and competitors in local market. Kuo et al.(2012) applied fuzzy set theory in ranking the failure risks obtained by applying Healthcare Failure Mode and Effect Analysis (HFMEA). Ranking has been done using TOPSIS. Büyüközkan&Çifçi (2012)has used fuzzy set theory in developing electronic service quality has used fuzzy AHP and fuzzy TOPSIS in measuring electronic service quality and finally implemented it in healthcare sector in Turkey to evaluate the performance of some leading hospitals' websites in Turkey. Dursun et al.(2011) proposed MCDM techniques for conducting an analysis based on multilevel hierarchical structure and fuzzy logic for evaluation of healthcare waste treatment alternatives.

Though there has been much study done in medicine using MCDM tools, not much research work has been done for the selection of best general anesthetic drug to the best of my knowledge. In this paper, we aim to find out the best anesthetic drug on the basis of few selected parameters. These parameters will act as a criteria for our decision-making problem.Also, since general anesthesia can be administered in two forms inhalational and intravenous so selection is done for both kind of drug. The variables chosen for the purpose are of fuzzy kind to better deal with the uncertainty and vagueness. For this, we have adopted the new fuzzy group multi-criteria decision making method originally developed by Mehlawat & Gupta (2016). The methodology is discussed in detail in next section.

Rest of the paper is organized as follows: under methodology section, methods used is discussed in details. In next section, numerical illustration is undertaken. Finally, in last section, results are discussed with some concluding remarks.

II. METHODOLOGY

Characteristic of ideal inhaled anesthetic drug is that it should has ample potency, low solubility in blood and tissues, should be resistant to physical and metabolic degradation, there should be lack of injury to vital tissues, lack of propensity to cause seizures, respiratory irritation and circulatory stimulation and should has low cost (Eger, 2004). Inhaled anesthetic drugs are considered as better drugs as they provide both analgesia and narcosis and hence can be used as both for induction and maintenance. While, the characteristics of ideal intravenous anesthetic agent is that it should has rapid onset of action, can be cleared through bloodstream and central nervous system quickly, protects vital tissues from damage, also provide other desirable pharmacologic effects like antiemetic effect, does not affect circulatory system and should has low cost (Eger, 2004). Inhalational techniques are most widely used in pediatric anesthesia since they are versatile, effective and easily controlled.

The parameters which we have selected as criteria for our problems are discussed in details. Few parameters has significance only for inhalational anesthetics while few are unique for intravenous anesthetic drugs.

1. Tissue: gas partition coefficients: They are helpful in determining the solubility of inhalational anesthetic in different solvents. Partition coefficients are simply the ratio of concentration of anesthetics in one solvent to the other and it tells how the anesthetic partitions itself between the two solvents at equilibrium. A low tissue: gas partition coefficient implies lower tissue solubility in blood. This difference in solubility of drugs in different solvents is important for its recovery from anesthesia. Different partition coefficients which are important in

terms of selection of anesthetic drugs are blood: gas partition coefficient, oil: gas partition coefficient, fat: gas partition coefficient, muscle: gas partition coefficient. Blood-gas partition coefficients are also known as Ostwald coefficient is the ratio of the concentrations of any compound in one solvent to the concentration in another solvent at equilibrium. It helps in determining how fast the drug will uptake into the blood. It is directly proportional to the solubility of that substance in the blood. It is also proportional to the potency of the drug. Hence, generally MAC decreases when blood: gas partition coefficient of the drug increases. While oil: gas partition coefficient is a measure of lipid solubility. Lipid solubility in turn is correlated with the potency of the drug. The different tissue: gas partition coefficients we are using in this paper are blood: gas partition coefficient, oil: gas partition coefficient, fat: gas partition coefficient and muscle: gas partition coefficient.

2. Tissue: blood partition coefficient: It represents the relative distribution of chemical between tissues and blood at equilibrium within the organism. Different tissue: blood partition coefficient, which we consider are brain: blood partition coefficient, fat: blood partition coefficient, muscle: blood partition coefficient. Brain-blood partition coefficient is the ratio of the anesthetic concentration between the blood and the brain tissues when partial pressures are equal. It is important as it determines the transportation and uptake into the brain. The transfer of inhalational anesthetic from the arterial blood to the brain depends on the blood-brain partition coefficient of the drug and the cerebral blood flow. It is directly proportional to the solubility of that substance in the brain tissues. While, fat: blood partition coefficient determines the distribution of volatile organic compounds between blood compartment, fat tissues and lipophilic cell membrane.

3. MAC: Minimal Alveolar Concentration is the measure of anesthetic potency. It is defined as the minimum alveolar concentration of anesthetic drug at 1 atm, which produces immobility in 50% of subjects exposed to the noxious stimulus, usually a skin incision (White, 2003). The alveolar concentration of the drug is assumed to be in equilibrium with that of the brain and for making this assumption hold true, sufficient time must be allowed for the brain concentration to come into equilibrium with that of the lung alveolus before a MAC determination is made. Potency of any drug is considered important factor as it protects vital tissues from damage. Anesthetic requirement decreases with that of the age because of the difference in rate of metabolism between different age group. Prof. Mappleson (Mapleson, 1996) concluded in his paper that from the age 1 year onwards, $\log_{10}$MAC decrease with age at the same rate for all inhaled anesthetic drugs. Greater the potency of the drug, lesser it would be required. MAC value is inversely related to the potency. Also, it is inversely correlated to the oil:gas partition coefficient.

4. Metabolism: Metabolism of the drug is the process by which the body breaks down and converts medication into active chemical substance. It involves the enzymatic conversion of therapeutically important chemical species to a new molecule inside the human body. So, basically it is the biotransformation of the drug in the body so that they can be eliminated out of the body more easily. It primarily takes place in the liver. It is important as it expected to promote recovery from the anesthesia. Metabolic rate vary from patient to patient and drug to drug and hence infants and elderly patients may have reduced capacity to metabolize certain drugs and may require adjustment in drug dosages.

5. Recovery time: It is the time period between anesthetic drug infusion and patient's eye opening without any mechanical assistance.

6. Half-life: It is the time taken for half of the initial dose of any drug to be eliminated from the body. It depends upon its clearance and volume of the distribution but elimination half-life is independent of the concentration of the drug present in the body. It is a useful parameter since it provides an exact indication of the length of the time that the effect of the drug persists in any individual.

7. Onset of action: It is the time period taken by drug to be effective after its infusion. An ideal drug should have rapid onset of action.

8. Induction dose: It is the amount of the drug given initially to achieve a desired level of the therapeutic concentration in the body. Since overdosing and under dosing is quiet common, hence induction dose should be carefully evaluated by considering various factors like patient's age, gender, weight and height.

9. Maintenance dose: It is the amount of the dose administered to a patient after initial induction dosage to maintain a desired level of hypnotism in the blood. It is generally given in small amounts.

10. Duration: It is the time period for which any particular drug is effective. Intravenous anesthetic drugs are generally not long-lasting and hence are given in addition to some other drugs to prolong its effect for surgeries.

11. Clearance: Drug clearance is the rate of removal of a particular drug out of the body. It can be obtained by dividing rate of elimination by plasma concentration of that drug. It can be dependent upon age and medical history of the patient. It is inversely related with the half-life of the drug.

12. Context sensitivity half time: It is the time required for blood or plasma concentrations of a drug to decrease by 50% after drug administration. It cannot be determined by elimination half as it also depends upon drug distribution. It helps in determining the duration of action of drug after stopping its infusion.

Parameters we have chosen for both inhalational and intravenous anesthetic drugs will act as criteria for our multi-criteria decision making model. Variables used are of fuzzy type to rely more with the vague and

uncertain data. The methodology adopted has been originally developed by Mehlawat & Gupta(2016). Stepwise description of the methodology is as follows:

Step 1: The aggregated fuzzy matrix is taken as follows:

$$\widetilde{D} = \begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{bmatrix} \text{and } W = [\widetilde{w}_1 \quad \ldots \quad \widetilde{w}_n],$$

where$\tilde{a}_{ij} = (a_{ij}, b_{ij}, c_{ij}); i = 1,2, \ldots, m, j = 1,2, \ldots, n.$

Step 2: This matrix is normalized using linear scale transformation adopted by Chen et al., (2006)to transform criteria scales into comparable scale. For this, criteria are categorized into benefitcriteria and negative criteria. For benefit criteria, the larger the rating, greater is the preference andfor negative criteria, smaller the rating, greater is the preference. Let J be the set of benefit criteriaand J' be the set of negative criteria with $J \cup J' = C$, the set of criteria. The normalized matrix is:

$\widetilde{R} = [\tilde{r}_{ij}]_{m \times n}$, where

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), j \in J; \; c_j^* = \max_i c_{ij}, j \in J,$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), j \in J'; \; a_j^- = \min_i a_{ij}, j \in J'.$$

Step 3: Calculate advantage and disadvantage of each alternative w.r.t. each criterion consideringthe performance of all other alternatives over the same criterion.

Advantage of i^{th} alternative relative with respect to j^{th} criterion is given by:

$$g_{ij} = \sum_{l \neq i} Q(\tilde{r}_{ij}, \tilde{r}_{lj}), \quad j = 1,2, \ldots, n.$$

Similarly, disadvantage of i^{th} alternative relative with respect to j^{th} criterion is given by:

$$h_{ij} = \sum_{l \neq i} Q(\tilde{r}_{lj}, \tilde{r}_{ij}), \quad j = 1,2, \ldots, n,$$

where$Q(\widetilde{A}, \widetilde{B})$ is fuzzy intensity function defined as

$$Q(\widetilde{A}, \widetilde{B}) = \begin{cases} \mu_F(\widetilde{A}, \widetilde{B}), & \text{if} \mu_F(\widetilde{A}, \widetilde{B}) \geq 0, \\ 0, & \text{otherwise}, \end{cases}$$

where$\mu_F(\widetilde{A}, \widetilde{B})$ is membership function defined for two triangular fuzzy numbers $\widetilde{A} = (a_1, b_1, c_1)$and $\widetilde{B} = (a_2, b_2, c_2)$ defined as:

$$\mu_F(\widetilde{A}, \widetilde{B}) = (a_1 + 2b_1 + c_1 - a_2 - 2b_2 - c_2)/2.$$

Step 4: Next, calculate the fuzzy strength and fuzzy weakness.

Fuzzy strength or weighted advantage of i^{th} alternative is defined as:

$$FS_i = \sum_{j=1}^{n} g_{ij} \widetilde{w}_j,$$

Similarly, fuzzy weakness is calculated as:

$$FW_i = \sum_{j=1}^{n} h_{ij} \widetilde{w}_j,$$

where$\widetilde{w}_j$ is the fuzzy importance weight assigned to each criterion.

Step 5: Calculate strength and weakness index score for each alternative using fuzzy strength andfuzzy weakness calculated in previous step.

Strength index score of i^{th} alternative is:

$$S_i = \sum_{l \neq i} Q(FS_i, FS_l) + \sum_{l \neq i} Q(FW_l, FW_i).$$

Similarly, weakness index score is:

$$W_i = \sum_{l \neq i} Q(FS_l, FS_i) + \sum_{l \neq i} Q(FW_i, FW_l).$$

Step 6: Finally, the total performance score or the ranking of i^{th} alternative is obtained by aggregatingstrength and weakness index score calculated in previous step.

$$P_i = \frac{S_i}{S_i + W_i}.$$

III. NUMERICAL ILLUSTRATION

In this paper, we attempt to make selection for both types of inhalational and intravenous anesthesia on the basis of parameters discussed above. The parameters we have selected will act as the criteria for our decision-making problem and different drugs chosen are acting as alternative for the problem. Alternatives for both inhalational and intravenous anesthetic are shown in **Table 1** and **Table 10** respectively. Different criteria, which are important for making a selection between different drugs is shown in **Table 2** and **Table 11** for both inhalational and intravenous anesthetic, respectively.

The performance of alternatives with respect to the selected criteria are shown in **Table 3** and**Table 12,** for inhalational and intravenous anesthetic respectively. Next, normalization is done using **Step 2**. Benefit criteria for inhalational anesthetic are C2, C3, C4, C5, C8, C9, C10, and C11 and negative criteria are C1, C6 and C7. For intravenous anesthetic, benefit criteria is C1 while negative criteria are C2, C3, C4, C5, C6 and C7. Next, using **Step 3**, the crisp advantage and disadvantage of each alternative with respect to each criterion is calculated. **Table 4**and **Table 5** presents respectively the obtained values of advantage and disadvantage scores for inhalational anesthetic.

Table 1 Alternatives with their description for inhalational anesthetic

Alternative	**Description**
A1	Isoflurane
A2	Desflurane
A3	Sevoflurane
A4	Enflurane
A5	Halothane
A6	Nitrous oxide
A7	Xenon
A8	Methoxyflurane

Table 2 Criteria name and their description for inhalational anesthetic

Criteria	**Description**
C1	MAC
C2	Blood:gas coefficient
C3	Oil:gas coefficient
C4	Fat:gas coefficient
C5	Muscle:gas coefficient
C6	Onset of action
C7	Recovery time
C8	Brain:blood coefficient
C9	Fat:blood coefficient
C10	Muscle:blood coefficient
C11	Metabolism

	A1	A2	A3	A4	A5	A6	A7	A8
C1	(1,1.15,1.17)	(6,6.6,7)	(1.71,1.8,2.05)	(1.6,1.63,1.68)	(0.7,0.75,0.77)	(100,104,106)	(70,71,72)	(0.1,0.16,0.18)
C2	(1.35,1.38,1.4)	(0.4,0.42,0.45)	(0.63,0.65,0.69)	(1.5,1.9,2)	(2,2.4,2.6)	(0.45,0.47,0.5)	(0.115,0.125,0.143)	(10,12,14)
C3	(95,97,100)	(18,18.7,20)	(50,53,55)	(95,98,98.5)	220	(1.2,1.4,1.6)	(1.6,1.9,2)	(950,960,970)
C4	(42,45,47)	(25,27,30)	(45,48,48)	(35,36,37)	(50,51,53)	(1.08,2,2.3)	(1,1.3,1.5)	(900,901,902)
C5	(2.1,3.6,4.4)	(0.62,0.78,0.94)	(1.1,1.7,2.4)	(1,1.2,1.4)	(3.8,7,9.5)	(0.5,0.53,0.55)	(0.09,0.092,0.1)	(1,1.4,1.5)
C6	(7,9,10)	(2,3,4)	(0.5,1,2)	(7,8,10)	(2,4,5)	(1,1.5,2)	(4,4.5,5)	(0.3,0.4,0.5)
C7	(11.5,18,30)	(3,5,10)	(5.5,7.8,10.1)	(3.6,6.1,8.6)	(8.83,10.6,12.3)	(10,10.1,10.5)	(2.3,5,7.9)	(30,32,35)
C8	(1.6,2,2.6)	(1,1.3,1.5)	(1.5,1.7,2)	(1.3,1.5,1.7)	(1.9,2,2.9)	(1,1.1,1.5)	(2.5,2.6,3)	(1.4,1.8,2)
C9	(40,45,47)	(25,27,30)	(45,48,50)	(35,36.2,38)	(55,60,62)	(2,2.3,2.5)	(9.5,9.6,10)	(38,45,48.8)
C10	(2.9,3.5,4)	(1.5,2,2.2)	(3,3.1,3.5)	(1.5,1.7,2)	(3,3.5,4)	(1,1.2,1.7)	(0,0.1,2)	(1.3,1.5,1.6)
C11	(0.15,0.17,0.2)	(0,0.02,0.1)	(3,5,8)	(5,8,10)	(15,25,40)	0	(0,0.01,0.01)	(45,50,51)

Table 3 Performance of alternatives w.r.t. various criteria for inhalational anesthesia

Table 4 Crisp advantage scores for inhalational anesthetic

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	0.63	0.55	0.65	0.25	3.14	0.00	0.00	1.88	3.27	5.36	0.02
A2	0.06	0.04	0.07	0.11	0.20	1.36	4.22	0.07	1.37	1.34	0.00
A3	0.29	0.13	0.28	0.28	0.99	12.42	0.91	0.82	3.95	4.46	0.82
A4	0.34	0.87	0.65	0.17	0.46	0.00	2.01	0.37	2.25	0.94	1.31
A5	1.17	1.32	2.17	0.33	8.15	1.23	0.03	2.48	6.55	5.45	5.66
A6	0.00	0.06	0.00	0.00	0.09	4.92	2.56	0.00	0.00	0.36	0.00
A7	0.00	0	0.00	0.00	0.00	0.34	0.47	4.70	0.24	0.00	0.00
A8	9.10	10.97	12.85	13.52	0.57	27.88	0.05	0.88	3.27	0.56	11.90

Table 5 Crisp disadvantage scores for inhalational anesthetic

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	1.31	1.72	2.03	1730.50	1.92	9.49	2.50	0.52	0.60	0.01	3.43
A2	1.93	2.31	2.75	1888.00	2.09	6.85	0.00	2.83	3.08	2.19	3.46
A3	1.54	2.13	2.40	1715.50	1.90	2.21	1.08	1.18	0.37	0.31	2.64
A4	1.49	1.53	2.03	1800.50	2.00	9.46	0.42	1.93	1.61	2.59	2.34
A5	1.13	1.38	1.53	1699.50	1.88	6.98	2.28	0.32	0.00	0.00	0.89
A6	2.10	2.26	2.97	2192.86	2.43	4.71	0.24	3.30	8.15	3.81	3.47
A7	2.10	2.60	2.96	2200.84	2.44	8.46	1.52	0.00	6.48	6.35	3.47
A8	0.00	0.00	0.00	0.00	0.00	0.00	2.22	1.12	0.60	3.21	0.00

For intravenous anesthetic, advantage and disadvantage scores are presented in **Table 13, Table 14** respectively. After that, using **Step 4** fuzzy strength and fuzzy weakness of each alternative is calculated using criteria weights. Here, we have allotted the hypothetical weight to the criteria. Experts help can be taken to evaluate the same. Weights we have assumed is given in **Table 6** and **Table 15.** Fuzzy strength and fuzzy weakness scores are shown in **Table 7** and **Table 16** for both types of anesthetic drug. These strengths and weakness index scores are calculated using **Step 5** and obtained values are given in **Table 8** and **Table 17** respectively for both types of drugs. Using **Step 6**, performance index or priority scores which act as ranking for different chosen anesthetic drugs for inhalational anesthesia and intravenous anesthesia are shown in **Table 9** and **Table 18** respectively. As per the results obtained in **Table 9**, A8 gets the highest performance scores and hence can be considered as the best inhalational anesthetic. From **Table 18,** we can deduct B8 as the best anesthetic drug chosen. Though the results obtained depend highly on the importance weights given to different criteria. So, any involvement of expert will enhance the quality of results obtained.

Table 6 Weights given to various criteria for inhalational anesthetic

Criteria	Weights
C1	(1,3,5)
C2	(1,7,9)
C3	(3,7,10)
C4	(5,8,10)
C5	(6,8.4,10)
C6	(5,7,9)
C7	(3,7,9)
C8	(3,5,8)
C9	(2,6,8)
C10	(2,5,6)
C11	(3,5,4)

Table 7 Fuzzy strength and weakness scores of alternatives for inhalational anesthetic

	FS	**FW**
A1	(46.17, 68.23, 90.57)	(8741.14,13997.61,17497.14)
A2	(27.15, 64.35, 97.64)	(9528.69, 15271.58, 19094.73)
A3	(95.14, 228, 201.85)	(8626.89, 13822.24, 17279.37)
A4	(24.24, 53.71, 79.72)	(9093.38, 14563.32, 18208.67)
A5	(114.17, 153.95, 181.77)	(8561.24, 13706.39, 17136.58)
A6	(33.61, 84.09, 85.37)	(11060.65, 17742.68, 22186.36)
A7	(17.69, 32.64, 49.62)	(11115.32, 17830.25, 22289.92)
A8	(315.18, 751.27, 743.74)	(17.63,40.78, 52.98)

Table 8 Strength and weakness scores of alternative for inhalational anesthetic

	Strength index	**Weakness index**
A1	18340.74	52441.55
A2	9813.96	63725.95
A3	15217.44	50765.30
A4	21296.38	57007.46
A5	1097.38	50254.25
A6	138.99	92346.06
A7	206611.50	93992.20
A8	188016.38	0.00

Table 9 Performance scores and ranking of alternatives for inhalational anesthetic

Alternatives	**Performance index**	**Ranking**
A1	0.259	4
A2	0.133	6
A3	0.231	5
A4	0.272	3
A5	0.021	7
A6	0.002	8
A7	0.687	2
A8	1.000	1

Table 10 Alternatives with their description for intravenous anesthetic

Alternative name	**Description**
B1	Propofol
B2	Ketamine
B3	Etomidate
B4	Methohexital
B5	Thiopental
B6	Midazolam
B7	Diazepam
B8	Fentanyl
B9	Atracuriumbesylate
B10	Cisatracuriumbesylate
B11	Lorazepam
B12	Pancuronium

Table 11 Criteria with their description for intravenous anesthetic

Criteria	**Description**
C1	Onset of action (s)
C2	Duration (min)
C3	Dose induction (mg/kg)
C4	Maintenance dose (mg/kg/min)
C5	Elimination half-life (hour)
C6	Context sensitive half-life (min)
C7	Clearance (ml/kg/min)

	C1	C2	C3	C4	C5	C6	C7
B1	(15,40,60)	(3,5,10)	(1.5,2,3)	(0.05,0.2,0.3)	(0.67,1.5,3)	(20,35,40)	(2,8,10)
B2	(10,30,120)	(5,10,15)	(0.5,1.5,2)	(0.01,0.02,0.03)	(2,3,3)	(20,30,40)	(2,3,3)
B3	(15,30,60)	(3,5,12)	(0.2,0.3,0.6)	(0.03,0.03,0.1)	3	(5,15,20)	(15,18,20)
B4	(15,60,60)	(4,6,7)	(1,1.5,2)	(0.2,0.23,0.25)	(3.8,4,4.5)	(30,200,250)	(4.5,8,9)
B5	(5,20,30)	(5,7.5,10)	(3,4.5,7)	0.16	(7,12,17)	(60,150,170)	(1.5,2,3)
B6	(30,45,60)	(15,22.5,3)	(0.025,0.1,0.3)	(0.01,0.02,0.06)	(2,3,4)	(60,65,70)	(5.55,8,10.4)
B7	(60,250,300	(15,50,60)	(0.1,0.3,0.4)	(0.05,0.1,0.166)	(30,180,200)	(10,120,150)	(0.14,0.32,0.59)
B8	(60,300,350)	(30,50,60)	(0.002,0.015,0.02)	(0.001,0.002,0.003)	(5,6,8)	(50,250,280)	(21,25,29.4)
B9	(200,240,260)	(30,35,40)	(0.4,0.5,0.6)	(0.08,0.1,0.12)	(19,20,21)	(20,30,35)	5.5
B10	(150,180,360)	(30,38,40)	0.1	0.03	(20,29,35)	(22,24,25)	(5.5,6.6,7.7)
B11	(60,250,300)	(720,1440,2000)	(0.02,0.05,0.06)	(0.002,0.005,0.008)	(15,18,20)	(500,600,720)	(1.1,1.2,1.5)
B12	(45,50,90)	(60,100,120)	(0.1,0.12,0.15)	(0.015,0.01,0.12)	(80,103,126)	(25,35,40)	(1.5,1.7,1.9)

Table 12 Performance of alternatives w.r.

Table 13 Crisp advantage scores for intravenous anesthetic

	C1	C2	C3	C4	C5	C6	C7
B1	0.14	8.42	0.00	0.01	9.32	1.24	0.16
B2	0.30	3.47	0.01	0.62	3.21	1.43	0.48
B3	0.08	8.15	0.05	0.19	2.68	8.00	0.00
B4	0.33	6.79	0.00	0.00	1.74	0.17	0.06
B5	0.00	4.63	0.00	0.00	0.39	0.08	0.76
B6	0.24	3.70	0.45	0.56	2.93	0.31	0.05
B7	6.74	0.38	0.08	0.03	0.00	1.09	10.72
B8	8.91	0.20	7.22	11.76	0.98	0.06	0.00
B9	7.84	0.32	0.02	0.02	0.12	1.51	0.11
B10	6.87	0.29	0.24	0.26	0.07	2.10	0.07
B11	6.74	0.00	0.88	4.56	0.16	0.00	1.60
B12	0.67	0.06	0.18	0.81	0.00	1.07	0.99

Table 14 Crisp disadvantage scores for intravenous anesthetic

	C1	C2	C3	C4	C5	C6	C7
B1	5.48	0.00	0.95	2.06	0.00	0.78	1.40
B2	5.06	1.65	0.94	1.47	0.56	0.68	1.17
B3	5.76	0.02	0.87	1.78	0.70	0.00	1.77
B4	5.01	0.30	0.95	2.14	1.16	2.25	1.52
B5	6.67	1.01	0.97	2.10	2.29	2.51	1.03
B6	5.17	1.48	0.66	1.50	0.61	1.96	1.56
B7	0.33	4.74	0.83	2.00	3.18	0.89	0.00
B8	0.00	5.16	0.00	0.00	1.71	2.61	1.82
B9	0.10	4.82	0.90	2.02	2.70	0.65	1.45
B10	0.29	4.87	0.73	1.71	2.85	0.54	1.50
B11	0.33	6.52	0.58	0.65	2.62	3.30	0.83
B12	4.67	5.83	0.76	1.40	3.22	0.90	0.95

Table 15 Weights given to various criteria for intravenous anesthetic

Criteria	Weights
C1	(6,7,9)
C2	(5,8,9)
C3	(3,5,7)
C4	(3,5,8)
C5	(3,5,6)
C6	(5,7,8)
C7	(6,7,9)

Table 16 Fuzzy strength and weakness scores of alternatives for intravenous anesthetic

	FS	**FW**
B1	(78.090, 124.797, 144.412)	(54.166, 68.616, 91.221)
B2	(40.659, 62.361, 73.895)	(57.867, 76.314, 97.921537)
B3	(90.013, 136.376, 156.052)	(55.279, 69.556, 92.388)
B4	(42.379, 66.968, 76.459)	(64.632, 85.040, 110.110)
B5	(29.325, 44.948, 51.585)	(79.891, 106.364, 135.810)
B6	(33.599, 53.478, 63.558)	(65.877, 86.516, 109.844)
B7	(112.471, 133.484, 170.149)	(48.169, 76.520, 93.662)
B8	(114.623, 164.161, 232.929)	(54.888, 80.824, 93.939)
B9	(57.339, 69.602, 87.564)	(53.505, 82.060, 101.194)
B10	(55.279, 68.429, 86.024)	(53.711, 81.794, 100.241)
B11	(66.855, 86.394, 118.678)	(67.627, 102.653, 120.535)
B12	(18.570, 24.536, 31.774)	(83.580, 119.276, 146.214)

Table 17 Strength and weakness scores of alternatives for intravenous anesthetic

	Strength index	**Weakness index**
B1	1300.85	163.99
B2	353.39	768.28
B3	1488.21	95.99
B4	278.60	830.88
B5	55.65	1601.39
B6	190.99	1058.84
B7	1601.62	73.31
B8	2226.99	34.61
B9	424.91	633.19
B10	410.91	647.19
B11	544.72	755.60
B12	0.00	2213.58

Table 18 Performance scores and ranking of alternatives for intravenous anesthetic

	Performance score	**Ranking**
B1	0.89	4
B2	0.32	8
B3	0.94	3
B4	0.25	9
B5	0.03	11
B6	0.15	10
B7	0.96	2
B8	0.98	1
B9	0.40	6
B10	0.39	7
B11	0.42	5
B12	0.00	12

IV. CONCLUSION

Selecting the best anesthetic drug before any surgical process is a crucial decision taken by anestheologist depending upon many factors like type of surgery, patient's medical condition and lots many factors. In this study, we attempted to undertake smaller part of this complex problem. For both types of anesthesia administration techniques i.e. inhalational and intravenous, we attempt to find out the best among available anesthetic drug on the basis of various criteria using MCDM technique. For this, we considered different drugs as alternatives and different important factors, which are important while making a selection, as criteria for the problem. Using a fuzzy technique, selection has been done based on critical criteria. More criteria like cost, BMI, descriptive factors like gender, etc., can be further added to make the problem more realistic. Also, anestheologist make selection on the basis of the kind of population that is, age group therefore this problem can further be sub-divided for different kind of population like pediatric patients, adults and older-aged patients by taking care of factors (criteria) important to that sub-group for example, anestheologist generally do not use inhalational anesthesia for neonates because of the small tracheal tube in such patients. This problem can be useful for anestheologist for making selections.

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