Anesthesiology Risk Analysis Model

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ABSTRACT

This paper focuses on the human error identified as an important risk factor in the occurrence of the anesthesia-related deaths. Performing clinical root cause analysis, the common anesthesia errors and their causes classified into four major problems (i.e., breathing, drug, technical, and procedural problems) are investigated. Accordingly, a qualitative model is proposed that analyzes the influence of the potential causes of the human errors in these problems, which can lead to anesthetic deaths. Using risk measures, this model isolates these human errors, which are critical to anesthesiology for preventive and corrective actions. Also, a Markovian model is developed to quantitatively assess the influence of the human errors in the major problems and subsequently in anesthetic deaths based on 453 reports over nine month.

Keywords: Anesthesia, Medical Systems, Human Errors, Markov Model.

1. INTRODUCTION

Anesthesiology concerns with the process of turning a patient into insensitive to the pain, which results from chronic disease or during surgery. A variety of drugs and techniques can be used to maintain anesthesia. When anesthesia is induced, the patient needs respiratory support to keep the airway open, which requires special tools and techniques. For example, it is advantageous to provide a direct route of gases into the lungs, so an endotracheal tube is placed through the mouth into the wind pipe and connected to the anesthesia system. A cuff on the tube provides an airtight seal. To place the tube, the patient's muscles must be paralyzed with a drug such as Curare. The drugs usually have some effects on the cardiovascular system. Therefore, anesthetist must monitor these effects (i.e., blood pressure, heart rate, etc). Unfortunately, there is not a fixed dose of most drugs used in anesthesia; rather, they are subjectively used by their effects on the patient. Generally, the anesthetist is engaged in a number of activities during the operation as follows:
monitoring the patient and the life support,
recoding the vital sings at least every 5 minutes,
evaluating blood loss and urine output,
adjusting the anesthetic level and administrating the medications, IV fluids, and blood, and
adjusting the position of the operation room table.
During this processes, there are some factors that cause complication or anesthetic death. In 1954, Beecher and Todd investigation on the deaths resulted from anesthesia and surgery showed that the ratio

of anesthesia-related death was 1 in 2680 [1]. In 1984, Davis and Strunin investigated the root causes of anesthetic-related death over 277 cases that depicted faulty procedure, coexistent disease, the failure of postoperative care, and drug overdose were major reasons of the deaths [2]. They showed the anesthetic-related death ratio was decreased from 1 in 2680 to 1 in 10000 because of taking pre-caution and post-caution measures. Even though human error was reported as a cause of anesthetic-related death for the first time in 1848, it took a long time to take the attention of the researchers toward such factor [3,4]. Cooper (1984) and Gaba (1989) studied human error in anesthetic mishaps in the United States that showed every year 2000 to 10000 patients die from anesthesia attributed reasons [5,6]. Reviewing the critical incidents in a teaching hospital, Short et al. (1992) concluded that human error was a major factor in 80% of the cases [7]. There exist some researches witnessed human error is a major factor in anesthesia-related deaths [8, 9, 10, 11]. In 2000, the role of fatigue in the medical incident was studied by reviewing 5600 reports in Australian incident monitoring database for the period of April 1987 to October 1997. In 2003, an anesthetic mortality survey conducted in the US that depicted the most common causes of perioperative cardiac arrest were medication events (40%), complications associated with central venous access (20%), and problems in airways management (20%). Also, the risk of death related to anesthesia-attributed perioperative cardiac arrest was 0.55 per 10,000 anesthetics [13]. In 2006, among the 4,200 death certificates analyzed in France, 256 led to a detailed evaluation, which depicted the death rates totally or partially related to anesthesia for 1999 were 0.69 in 100,000 and 4.7 in 100,000 respectively [14, 15].

In Anesthesiology, human error is defined either as an anesthesiologist's decision, which leads to an adverse outcome or an anesthesiologist's action, which is not in accordance with the anesthesiology protocol. In this paper, we study the frequent anesthesia errors, their causes, and modes of human error in anesthesia in order to develop qualitative and quantitative models for assessing the influence of the human errors in anesthetic deaths. Subsequently, a rule of thumb is proposed to reduce the influence on human errors in anesthetic deaths.

2. COMMON HUMAN ERRORS AND THEIR CAUSES IN ANESTHESIOLOGY

Figure 1 shows four types of anesthetic problems that can cause complication or death. The cause and effect diagram presents breathing, drug, procedural and technical problems, which can be triggered by common anesthesia errors.

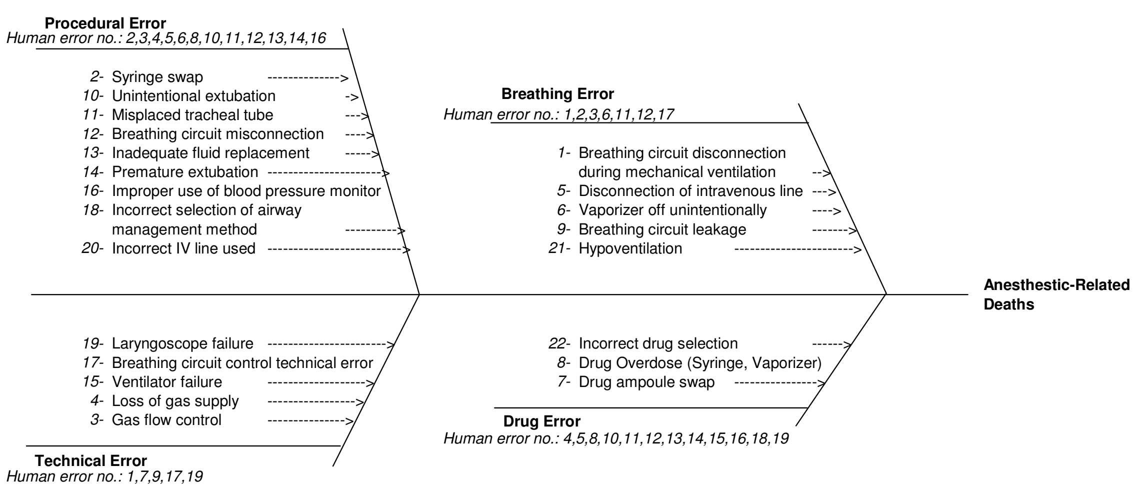

FIGURE 1: Cause and effect diagram for anesthesia-related deaths

Using root cause analysis, Table 1 presents the common anesthesia errors and their risk priority number (RPN). The RPN value for each potential error can be used to compare the errors identified within the analysis in order to make the corresponding improvement scheme. Using Tables 2 and 3, the RPN is multiplication of the rank of occurrence frequency and of the rank of severity. These common errors can result from human errors, which are believed to be responsible for 87% of the cases, presented in Table 4. The human errors contributing in the anesthetic error are indicated in the cause and effect diagram in Figure 2. This qualitative diagram along with RPN points out the required modifications to reduce the ratio of anesthesia-related deaths.

Code	Error No.	Description	R.P.N
C01	1-	Breathing circuit disconnection during mechanical ventilation	90
C02	2-	Syringe swap	90
C03	3-	Gas flow control	81
C04	4-	Loss of gas supply	72
C05	5-	Disconnection of intravenous line	72
C06	6-	Vaporizer off unintentionally	64
C07	7-	Drug ampoule swap	56
C08	8-	Drug Overdose (Syringe, Vaporizer)	56
C09	9-	Breathing circuit leakage	56
C10	10-	Unintentional extubation	49
C11	11-	Misplaced tracheal tube	42
C12	12-	Breathing circuit misconnection	42
C13	13-	Inadequate fluid replacement	42
C14	14-	Premature extubation	36
C15	15-	Ventilator failure	30
C16	16-	Improper use of blood pressure monitor	25
C17	17-	Breathing circuit control technical error	20
C18	18-	Incorrect selection of airway management method	16
C19	19-	Laryngoscope failure	12
C20	20-	Incorrect IV line used	8
C21	21-	Hypoventilation	4
C22	22-	Incorrect drug selection	2

Table 1: Common anesthesia errors

Linguistic terms for probability of occurrence	Rate	Rank
Extremely high	>1 in 2	10
Very high	1 in 3	9
Repeated errors	1 in 50	8
High	1 in 200	7
Moderately high	1 in 1000	6
Moderate	1 in 2000	5
Relatively low	1 in 5000	4
Low	1 in 15,000	3
Remote	1 in 50,000	2
Nearly impossible	1 in 100,000	1

Table 2: Ranking system for the probability of occurrence of human error

Linguistic terms for severity	Rank
Hazardous	10
Serious	9
Extreme	8
Major	7
Significant	6
Moderate	5
Low	4
Minor	3
Very minor	2
None effect	1

Table 3: Ranking system for the severity of an error

In Figure 2, the RPN of the common anesthesia errors is presented in the circles that are calculated based upon severity×occurrence ranking rates obtained from experts. To compute the RPN for the anesthesia problems shown in double-line circles, the RPN of common anesthesia errors and the ranking system of the frequency of human error are amalgamated by using Equation (1).

RPN Anesthesia problem = Max{RPN common errors 1, RPN common errors 2, ….., RPN common errors n}×

Max{RPN Max of human error 1, RPN Max of human error 2,….., RPN Max of human error m} (1)

As shown in Figure 2, the risk priority number for breathing, procedural, technical, and drug errors are 900, 810, 810, and 512, respectively. This leads to very high risk for anesthesia-related deaths.

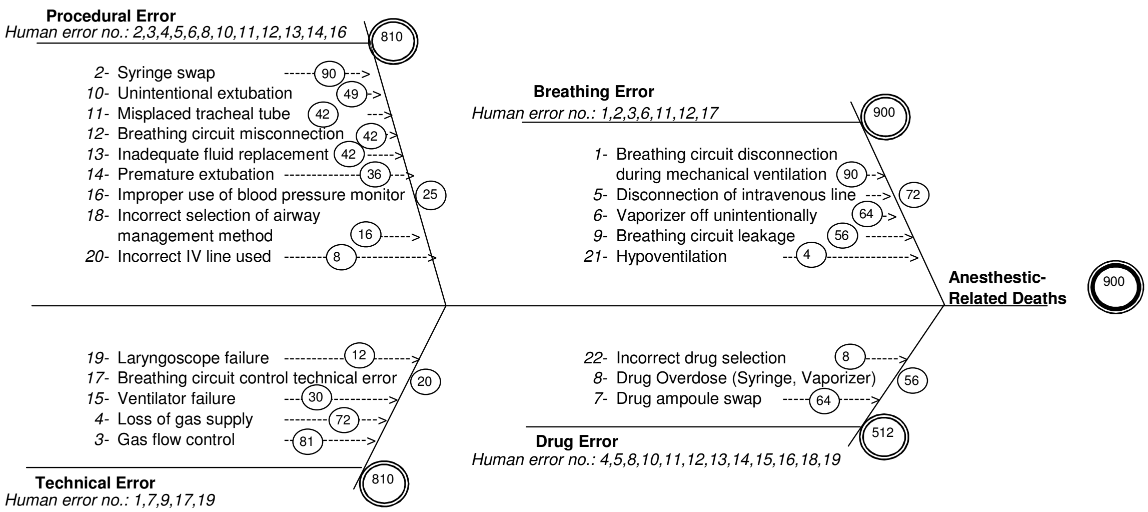

FIGURE 2: RPN of the common errors causing anesthesia-related deaths

To illustrate the RPN calculation, consider the procedural problem. The maximum RPN of common causes contributing in this problem is 90 from syringe swap (see Figure 2). Also, the maximum RPN related to human errors causing these common causes is 90 obtained from Table 1. Therefore, the RPN of the procedural problem is $90\times9=810$.

Code	Cause No.	Description	Frequency Of Occurrence
H01	1	Failure to check	10
H02	2	Very first experience with situation	9
H03	3	Poor total experience	9
H04	4	Carelessness	8
H05	5	Haste	8
H06	6	Unfamiliarity with anesthesia method	8
H07	7	Visual restriction	7
H08	8	Poor familiarity with anesthesia method	7
H09	9	Distractive simultaneous anesthesia activities	7
H10	10	Over dependency on other people	6
H11	11	Teaching in progress	6
H12	12	Unfamiliarity with surgical procedure	5
H13	13	Fatigue	5
H14	14	Lack of supervisor's presence	5
H15	15	Failure to follow personal routine	4
H16	16	Poor supervision	3
H17	17	Conflicting equipment designs	2
H18	18	Unfamiliarity with drug	1
H19	19	Failure to follow institutional practices and procedure effectively	1

Table 4: Human errors in anesthesia

To reduce such risk, the rule of thumb is proposed that includes
Perform periodic inspection,
Have mandatory supervision, and
Fill out the procedural check sheet.
This rule of thumb helps in elimination of human errors contributing in the major anesthesia problems. As result, the RPN is reduced to 245 as shown in Figure 3. The calculation still shows further improvement is required to reducing the RPN of anesthesia-related death that is resulted from procedural and technical errors.

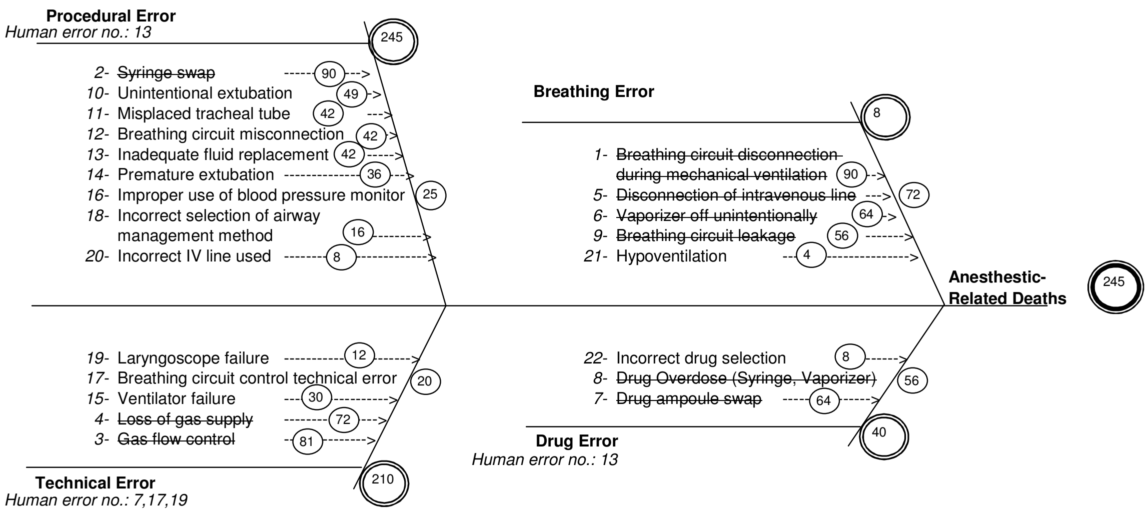

FIGURE 3: Improved RPN of the common errors using the rule of thumb

3. MARKOVIAN MODEL FOR ASSESSING THE HUMAN ERROR IN ANESTHETIC-RELATED DEATHS

This quantitative model is developed to study the human error influence in anesthetic-related deaths. The model is made up several states representing start, human errors, anesthesia problems (i.e., the procedural, breathing, technical, and drug problems), and anesthetic-related deaths. In Figure 4, the state diagram depicts the relations and transition rates among these states. The states corresponding to the human errors are presented by their codes in Table 4 and the anesthesia problems are denoted by P01, P02, P03, and P04.
To solve this Markov model, an excel macro is developed that need transition rates shown in Table 5. The obtained result from the macro shows that the probability of anesthetic-related deaths is 0.0003 and probability of the procedural, breathing, technical, and drug problems is 0.48, 0.29, 0.06, and 0.03, respectively. Also, in conjunction with the cause and effect diagram, the RPN order of these problems is the same. Therefore, the precaution measures proposed in qualitative can reduce the probabilities.

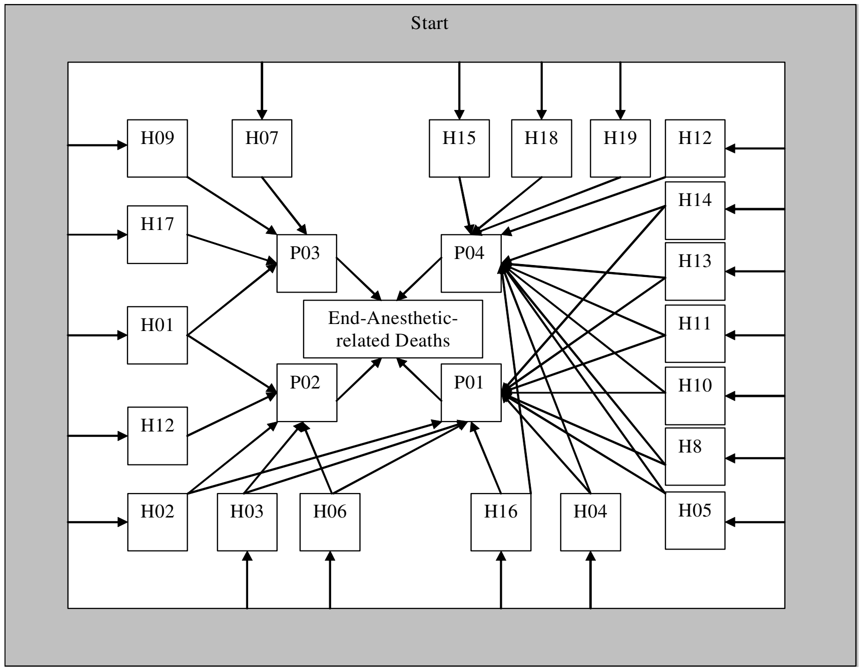

FIGURE 4: Anesthetic-related death state diagram

From		To	Rate (FITs)	From		To	Rate (FITs)
H1	→	H2	2002.5	H6	→	P1	140.25
H1	→	H3	1802.25	H6	→	P2	140.25
H1	→	H4	1802.25	H7	→	P3	201.5
H1	→	H5	1602	H8	→	P1	152.25
H1	→	H6	1602	H8	→	P4	152.25
H1	→	H7	1602	H9	→	P3	329.75
H1	→	H8	1401.75	H10	→	P1	75
H1	→	H9	934.5	H10	→	P4	75
H1	→	H10	934.5	H11	→	P1	112.75
H1	→	H11	801	H11	→	P4	112.75
H1	→	H12	801	H12	→	P2	150
H1	→	H13	667.5	H12	→	P4	150
H1	→	H14	333.75	H13	→	P1	350
H1	→	H15	333.75	H13	→	P4	350
H1	→	H16	267	H14	→	P1	225
H1	→	H17	80.1	H14	→	P4	225
H1	→	H18	53.4	H15	→	P4	75
H1	→	H19	13.35	H16	→	P1	50
H2	→	P1	306.5	H16	→	P4	50
H2	→	P2	306.5	H17	→	P3	100
H3	→	P1	256	H18	→	P4	75
H3	→	P2	256	H19	→	P4	112.5
H4	→	P1	505.25	P01	→	END	28

H4	→	P4	505.25	P02	→	END	22
H5	→	P1	407	P03	→	END	160
H5	→	P4	407	P04	→	END	150

Table 5: Transition rates of the anesthetic-related death Markov model

4. CONCLUSIONS

This paper studies the human errors in anesthesiology and measures the risk associated with these errors. The cause and effect diagram is used to identify the potential major problems in anesthesiology and their relationship with human errors, which may lead to death. The results depict the risk of anesthetic related death is very high and it can be reduced by applying simple rules that mitigate human errors. Also, Markovian model is used to compute the probabilities of occurrence of each major procedural, breathing, technical, and drug problems. In conjunction with the cause and effect results, this analysis confirms the procedural and breathing are utmost reported problems.

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