Nursing Fuzzy Expert System for Preventing Pressure Ulcer Development in Surgical Patients

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Abstract--**This paper describes a nursing fuzzy expert system for preventing pressure ulcer development in after surgical patients. First, knowledge of expert nurse are derived. Second, this system is constructed by the simple calculation of fuzzy membership functions expressing the knowledge. The expert system produces a fuzzy degree by averaging the calculated values by these membership functions. This system performance is demonstrated on data of 10 patients. Then, our nursing fuzzy expert system can determine the pressure ulcer development with better precision, compared with our past work by statistical analysis on 360 patients.**

I. INTRODUCTION

Pressure ulcer is a rough place on the skin which may caused by the pressure from a bed. (Pressure ulcer is defined as lesions on any skin surface that occur from unrelieved pressure and result in damage to underlying tissue). Especially, the incidence rates increased from 0.9％ to 15.6％ for surgical patients [1][2]. It is important to manage the surgical patients because several patients maintained that the pain of the pressure ulcer was larger than the pain of the invasiveness of the surgery. In the nursing, it is required for the nurse to determine the state of a patient in surgery. In it, the expert nurse can precisely determine the possibility to develop a pressure ulcer for the patient. This information is important to manage them. Therefore, this information usually transmitted from the OR (Operation room)nurse to the nurse in convalescence.

Expert system [3] is a branch of Artificial Intelligence that makes extensive use of specialized knowledge to solve problems at the level of human expert. An expert is a person who has expertise in a certain area. That is, the expert has knowledge or special skills that are not known or available to most people. A nursing expert system is also important to solve problems that most nurses cannot solve or only expert nurse can solve much more effectively.

In this paper we describe a nursing expert system for preventing the development of pressure ulcer based on fuzzy logic [4]. This system is necessary to effectively transmit the possibility for the pressure ulcer development from the OR expert nurse to the nurse in convalescence. By using this, the nurse in convalescence can effectively control pressure ulcer development. This study can also contribute the future advance on the knowledge and technology database in the nursing. In Konishi et.al. [5], we described the reasons to cause pressure ulcer on 360 patient data. In it, we extracted the factors for pressure ulcer by doing Hayashi's quantification analysis II. As the result, we discriminate the ulcer at the ratio of 76.5%. However, typical quantification analysis cannot treat continues numerical data such as Alb., TP., and Hb. Moreover, this analysis did involve no expert knowledge because this did on pure statistics. This paper proposes a nursing fuzzy expert system according to the knowledge of expert nurse with respect to pressure ulcer development. This system can manipulate the numerical data of patients, and it produces fuzzy degree expressing pressure ulcer development because the almost body data is numeric and the possibility of pressure ulcer development includes partial truth. In our experimental result on ten patients, our system can successfully determine the degree of pressure ulcer development. Thus, our nursing fuzzy expert system consisting of expert nurse knowledge can determine the degree of the development with better expression, compared with the method in Ref.[5].

II. PRELIMINARIES

First, cause of pressure ulcer development is explained. The pressure ulcer is developed for surgical patients satisfying the condition shown in Figure 1. As shown in Figure 1, the main mechanism is quite complex. The main reasons are tabulated in Table 1. The pressure ulcer in surgical patients primary depends on three characteristics: pre-operative characteristics of the patient body, characteristics of intra and post-operative treatment and invasive characteristics to the patient in the surgery. These characteristics cause ischemics through the pressure to a skin, and develop the pressure ulcer to the skin. Thus, it is known that these three conditions causes pressure ulcer development. However, it is difficult to determine whether or not a patient will be ulcerative. It is important to know that the patient should be received a care for preventing pressure ulcer beforehand. In the following sections, we describe the nursing expert system for finding the patients requiring the care of pressure ulcer.

In Konishi et.al. [5], we described a method to anticipate risk factors of pressure ulcer particular to each patient developed during operation on 360 records. The multivariate statistical analysis (Hayashi's quantification analysis II) on these data was done on nine items: surgical position, age, standard weight, operation time (time the position is kept), inhalation anesthetics usage, medication usage for circulation, past disease history, TP (total-proteine), and Hb (Hemoglobin). The weight for each item is summarized in characteristics. Then four characteristics: surgical position, standard weight, medication usage for circulation, Hb are signs, as shown in Table 1. In this analysis, we also did test

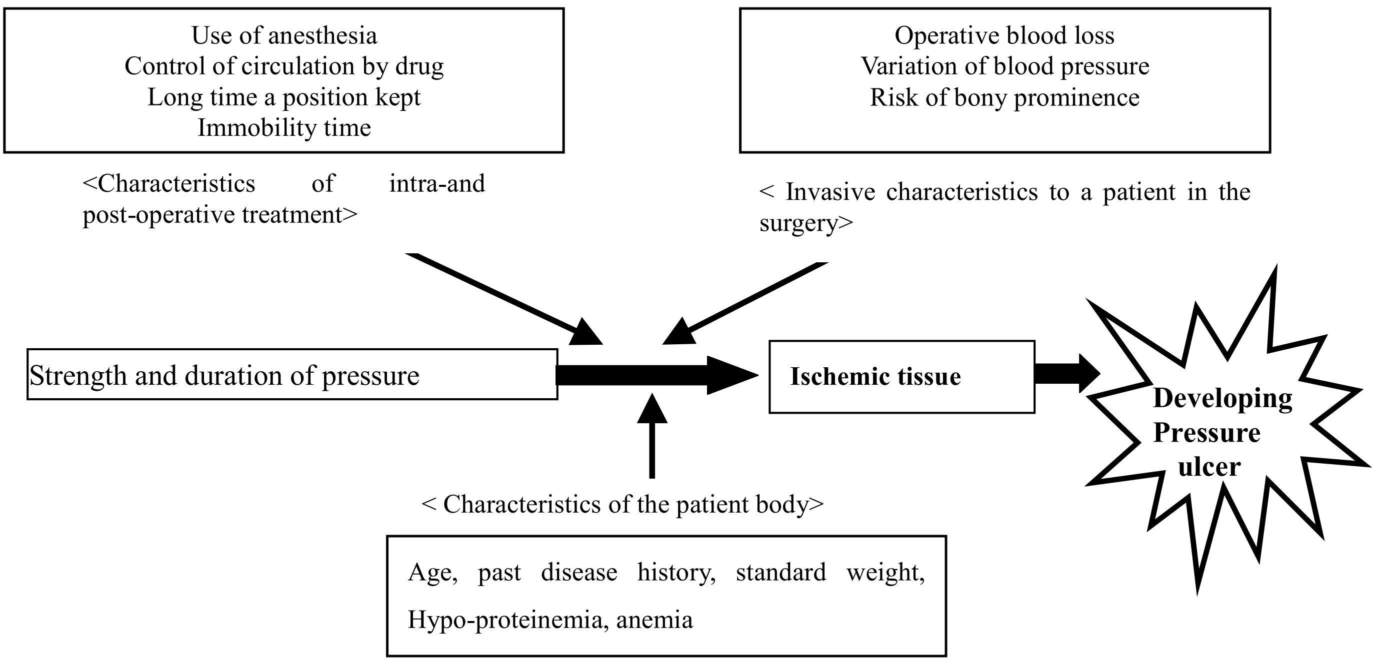

Figure 1 The Factor of developing pressure ulcer in surgical patient

Table 1 Characteristics of occasion with respect to pressure ulcer development

Pre-operative characteristics of the patient body.	**Characteristics of intra and post-operative treatment.**	**Invasive characteristics to the patient in the surgery.**
Age Standard weight past disease history pre-operative anemia (Hb: hemoglobin level) Pre-operative hypo-proteinemia (TP, serum albumin level)	Content of surgery Operation-time (time the position is kept) Surgical position Use of Epidural anesthesia Medication usage for circulation drug	Blood loss Variation of Blood pressure

for significantly different with significant level < 0.05. The discriminate values are as follows:
Pressure ulcer development: 0.967139
No pressure ulcer: -0.270813.
This method successfully discriminated these data at the accuracy of 76.5% with the discriminate level for the above values. In this method, we cannot determine whether or not pressure ulcer development for the values between –0.270813 and 0.967189.

Ⅲ. NURSING FUZZY EXPERT SYSTEM OF PRESSURE ULCER

This section proposes a nursing fuzzy expert system of pressure ulcer in surgical patients according to expert nurse knowledge. These expert knowledge for pressure ulcer development are shown as follows:

(Knowledge 1) Surgery position is an important factor.
(Knowledge 2) Heavy (Obese) patients will develop it than light (thin) patients.
(Knowledge 3) Medication usage for circulation prevents it.
(Knowledge 4) Older patients will develop it than the younger, and longer surgery time develops it more likely.
(Knowledge 5) Surgery content is an important factor.
(Knowledge 6) Hb, Alb and TP are important factors because these values show the state of anemia and nutrition.

Here, we show the factors that clearly contradict the fuzzy knowledge of expert nurse in our past work [5]. In Table 2, the results of age, operation time, TP clearly contradicted the knowledge (Knowledge 1) and (Knowledge 6). Expert nurse cannot accept these facts in Table 2.

In this paper, we propose the system in which the used knowledge (inference rule) do not contradict the expert nurse. First, we determine the characteristics according to the above knowledge. According to these knowledge, we derive the following characteristics.

(1) Surgical position (Knowledge 1)
(2) Standard weight (Knowledge 2)
(3) Medication usage for circulation (Knowledge 3)
(4) Operation time × age (Knowledge 4)
(5) Surgery contents (Knowledge 5)
(6) Hb(Knowledge 6)

Table 2 Characteristics of 360 patients' data and statistical analysis data.

Item		Ratio (%)	Weight
1.Surgical position (P<0.01)	Supine position	11.6	-0.929138
	Lateral position	37.1	0.780952
	Prone position	73.0	1.214073
2. Age	< 60	34.0	0.252262
	>= 60	27.8	-0.161707
3. Standard weight (P<0.05)	Suntexis	14.3	-0.708854
	Standard	34.6	0.082119
	Adiposis	32.8	0.121829
4. Operation time	< 2 hours	30.4	1.198142
	2 to 4 hours	36.3	-0.461331
	4 to 8hours	28.1	-0.170906
	> 8hours	28.6	0.605031
5. Inhalation anesthetics	Yes	34.1	0.193572
	No	20.5	-0.797516
6.Medication (P<0.05)	Yes	23.4	0.015303
	No	37.6	-0.637630
7. Past disease history	Yes	36.0	0.00
	No	28.5	-0.027577
8. TP	< 6.7	24	0.00
	>= 6.7	34.4	0.155178
9. Hb (P<0.05)	< M12.6	16.7	0.00
	>= M12.6	34.3	-0.543551

(7) Alb. (Knowledge 6)
(8) TP(Knowledge 6)

Second, we construct a fuzzy inference mechanism consisting these eight characteristics. In order to do it, we have obtained the new data of ten patients (seven female and three male). These all characteristics are shown in Table 3, where an expert nurse determines surgical content values. From numerical data of them, we calculate the mean and standard deviation for each of three groups: (i) pressure ulcer development, (ii) a little development and healed and (iii) no pressure ulcer. For nominal data, we show the frequency. These results are shown in Table 4. In our system, we employ a simple fuzzy inference mechanism by minimum between a membership function and the characteristic value. We make the fuzzy membership functions MF_i (i = 1(operation time × age), 2(Alb), 3(TP), 4(Hb), and 5(surgery contents)) for numerical characteristics. These membership functions are shown in Figure 2. We make the fuzzy membership functions MF_i (i = 6(standard weight), 7(surgical position) and 8(Medication usage)) are as follows,

$$MF_6 = \begin{cases} 1 \text{ if surgical position} = \text{prone position} \\ \quad 0 \text{ othwerwise} \end{cases}$$

$$MF_7 = \begin{cases} 1 \text{ if weight} = \text{suntexis} \\ 0.5 \text{ if weight} = \text{standard} \\ 0 \text{ if weight} = \text{adiposis} \end{cases}$$

$$MF_8 = \begin{cases} 0 \text{ if Mediciation is used} \\ 1 \text{ if Mediciation is not used} \end{cases}$$

Here, the expert nurse agreed the all membership functions for manipulating characteristics of pressure ulcer development. That is;

- Membership function of Operation time × age : Larger value becomes higher fuzzy degree.
- Membership functions of Hb, Alb. and TP: Smaller values become lower fuzzy degrees.
- Surgical contents: Larger value becomes higher fuzzy degree.
- Surgical Position, Prone is more likely than others
- Standard weight: More heavy (obese) patients become higher fuzzy degree.
- Medication usage: The used patients become lower degrees.

By the simple fuzzy inference mechanism, we calculate the fuzzy membership degree $\mu_i(a)$ (i = 1, 2, …, 8) for each characteristic value by,

$\mu_i(a)$=min(MF_i, $s_i(a)$),

where fuzzy singleton function s(x) is defined as s(a)=1 if x=a ; =0, otherwise on domain x. The calculated fuzzy membership degree, $\mu_i(a)$, expresses the fuzzy degree that represents the possibility to become pressure ulcer for characteristic i for input a.

Finally, we consider the combination rule for these fuzzy degrees. In this case, a total fuzzy degree expressing pressure ulcer development is calculated by average operation of them,

$\mu_{total}(a)$= Average $\mu_i(a)$ *for all i.*

The value, $\mu_{total}(a)$, shows a fuzzy degree expressing the fuzzy degree to develop pressure ulcer for a patient

This method is applied to the ten patients. The results are shown in Table 5. In Table 5, the results by Ref.[5] are also tabulated. Our fuzzy degrees, μ_{total}, successfully represent the pressure ulcer development for all patients, compared with these truth data. Moreover, as a comparison with Ref.[5], our method has successfully determined the possibility of pressure ulcer development for cases 3, 5, and 10.

Table 3 Characteristics of ten patients' data.

Patients	1	2	3	4	5	6	7	8	9	10
Surgical Position	S	S	S	S	P	S	S	S	S	S
Age	68	78	53	78	61	66	65	50	82	60
Standard Weight	ST.	ST	SU.	AD	AD	ST	SU	ST	AD	AD
Operation time × age	306	390	636	468	336	729	358	700	369	690
Medication usage	Y	Y	Y	N	N	Y	Y	Y	N	Y
TP	7.7	5.8	5.5	6.8	6.1	6.3	6.4	6.5	6.9	7.4
Hb	13.3	12.7	10.0	12.9	10.8	12.4	13.9	8.5	14.2	9.7
Alb	3.6	3.6	2.9	3.3	2.8	3.8	4.1	3.6	3.6	3.5
Surgical contents	0	0.5	1.0	0	0.5	1.0	0.3	1.0	0.3	1.0
Diseases History	N	N	N	Y	Y	N	N	N	N	Y
Inhalation(Epidural anesthesia)	N	Y	Y	N	N	Y	N	Y	Y	Y
Truth	N	N	Y	M	Y	N	N	Y	N	M

Surgical position (S: others P: Prone); Standard weight (ST: standard, SU: Suntexis, AD: Adiposis); Truth (N: no development, M: a little development and healed, Y: development)

Table 4 Mean and standard deviation of the characteristics.

Characteristics	(i)Development		(ii) A little development		(iii) No development	
	Mean	SD	Mean	SD	Mean	SD
(1) Operation time × age	557.1667	158.9048	579	111	429.7	150.7108
(2) Alb	3.1	0.356	3.4	0.1	3.74	0.195959
(3) TP	6.03	0.41	7.1	0.3	6.62	0.643117
(4) Hb	9.77	0.95	11.3	1.6	13.3	0.684105
(5) Surgery contents	0.833	0.2357	0.5	0.5	0.42	0.3089
(6) Standard weight	SU:1, ST: 1, AD:1		SU:0, ST:0, AD:2		SU:1, ST:3, AD. :1	
(7) Surgical position	P:1, S:2		P:0, S:2		P:0, S:5	
(8) Medication	Y: 2, N: 1		Y: 1, N:1		Y: 4, N:1	

IV. CONCLUSIONS

This paper has proposed a nursing fuzzy expert system. In Konishi et.al., we showed the statistical analysis results on 360 patients. However, these results included the knowledge which clearly contradict expert nurse ones. In the real nursing, expert nurses almost always determine correct judgments. In this work, we have proposed a nursing expert system consisting of knowledge of the expert nurse. In it, simple fuzzy calculation is employed to manipulate the knowledge and real data. The expert could agree the membership functions shown here. That is, the expert nurse agrees the fuzzy inference rules in the system. In the experimental results on ten patients, ours system has successfully determined the degree for pressure ulcer development in comparison with our past work.

In real nursing, if the defuzzification of our determined fuzzy degree, then simple alpha-cut below is meaningful.

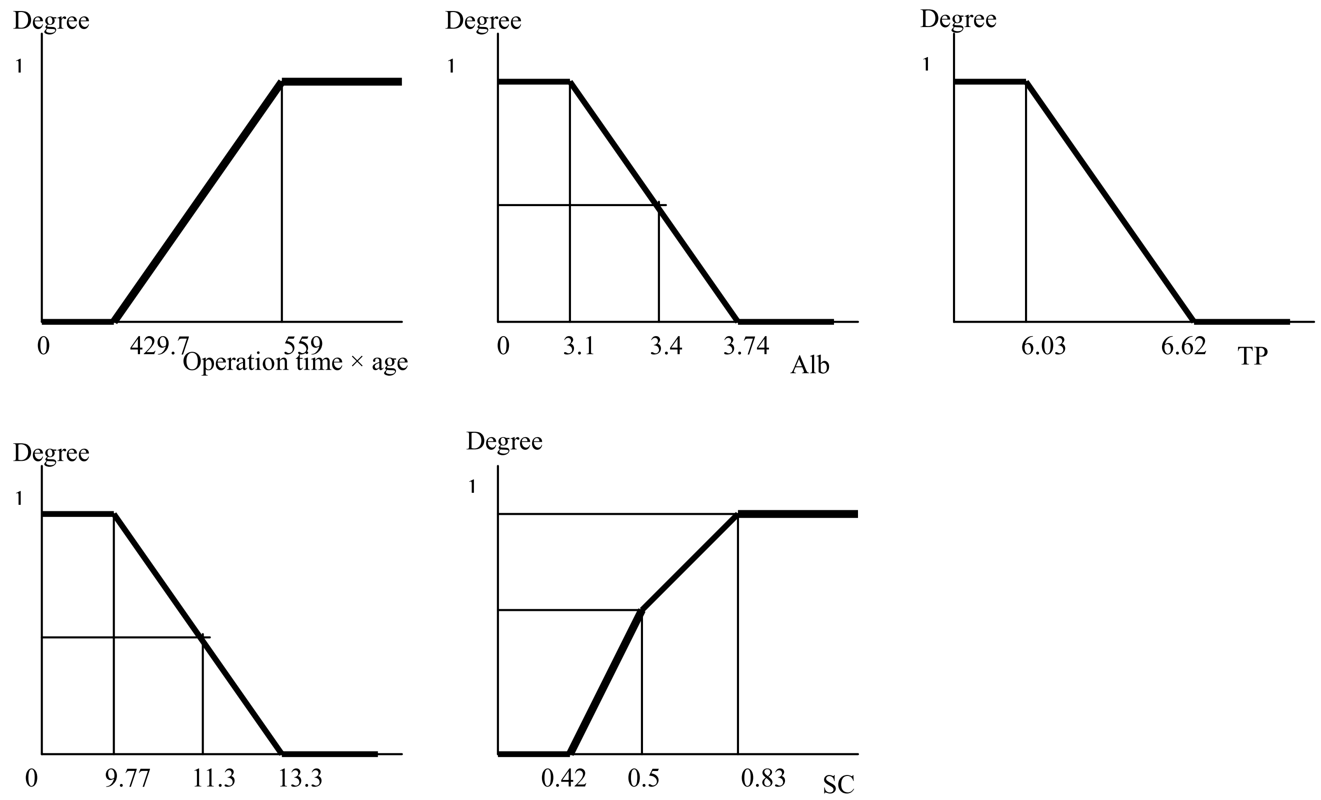

Figure 2 Fuzzy membership functions.

Table 5 Experimental results

Patients	1	2	3	4	5	6	7	8	9	10
(1) Operation time × age	0	0	1	0.2988	0	1	0	1	0	1
(2) Alb	0.208	0.208	1	0.656	1	0	0	0.208	0.208	0.355
(3) TP	0	1	1	0	0.8866	0.5478	0.3784	0.209	0	0
(4) Hb	0	0.15	0.932	0.1	0.6712	0.225	0	1	0	1
(5) Surgical position	0	0	0	0	1	0	0	0	0	0
(6) Standard weight	0.5	0.5	1	0	0	0.5	1	0.5	0	0
(7) Surgery contents	0	0	1	0	0.5	1	0	1	0	1
(8) Medication	0	0	0	0.5	0.5	0	0	0	0.5	0
Fuzzy degree μ_{total}	0.086	0.232	0.742	0.257	0.632	0.409	0.172	0.490	0.151	0.419
Method in Ref. [5]	-1.12108	3.962222	6.185186	3.475556	7.629259	6.740741	1.518519	6.747408	5.073333	5.951852
Result by Ref. [5]	N	N	-	N	N	-	N	Y	N	Y
Truth	N	N	Y	M	Y	N	N	Y	N	M

$$\text{Result} = \begin{cases} \text{Y if } \mu_{\text{total}}(a) \geq \text{Th1} \\ \text{M if Th1} > \mu_{\text{total}}(a) > \text{Th2} \\ \text{N otherwise.} \end{cases}$$

In our experimental results, we have demonstrated only ten patients. It remains as the future study to show the availability to other patients and to refine the mechanism of expert system engine.

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