

# The effect of operating room design and behavior of operating room staff on surgical site infection (SSI) incidence

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## ABSTRACT

Widodo and Iwan Dwiprahasto - *The effect of the change in operating room design and behavior of operating room staff on SSI incidence in Santa Maria Hospital, Pemalang*

**Introduction:** In surgery, medical error is often related to surgical site infection (SSI). Santa Maria Hospital, Pemalang, is a private hospital which gives priority to quality and applies the patient safety principle. During 2006, there were 7 cases of SSI in 785 surgical cases in Santa Maria Hospital, Pemalang, but this number was considered as the tip of an iceberg. The high microorganism rate, operating room design which was not agreeable with the standard by Kepmenkes No 1204/MENKES/SK/X/2004, and the behavior of operating room staff were the risk factors of SSI. **Objective:** To find out the effect of the change in operating room design and behavior of operating room staff on SSI incidence in Santa Maria, Pemalang, and to find out the risk factors of SSI.

**Method:** It was a quasi-experimental study with pre- and post-test without control group design. Population were all operating room staff, while subject of this study was operating room design. Dependent variable was SSI incidence, while independent variables were behavior of operating staff and operating room design. Data were analyzed with independent t-test, chi-square test, and multivariate logistic regression.

**Result:** The change in operating room design and operating room staff behavior has significantly decreased the incidence of SSI (OR = 3.646; 95%CI = 1.24 < OR < 10.77).

**Conclusion:** Intervention on operating room design and staff behavior has decreased the incidence of SSI. Risk factors of SSI were operating room design, operating room staff behavior, and duration of surgery.

**Key words:** surgical site infection (SSI) - staff behavior - operating room design

## ABSTRAK

Widodo dan Iwan Dwiprahasto - *Perubahan desain ruang operasi dan perilaku petugas di ruang operasi terhadap kejadian SSI di RS Santa Maria Pemalang dan mencari faktor risiko SSI*

**Latar belakang:** Di dalam bidang pembedahan *medical error* sering dikaitkan dengan *Surgical Site Infection* (SSI). RS Santa Maria Pemalang merupakan RS swasta yang mengutamakan mutu dan menerapkan prinsip *patient safety*. Selama tahun 2006 dari 785 kasus operasi didapatkan 7 kasus SSI di RS Santa Maria Pemalang akan tetapi kasus tersebut diduga sebagai fenomena gunung es. Tingginya angka kuman, desain ruang operasi yang tidak memenuhi persyaratan yang sesuai dengan Kepmenkes No 1204/MENKES/SK/X/2004 dan perilaku petugas di ruang operasi merupakan faktor risiko terjadinya SSI.

**Tujuan penelitian:** Untuk mengetahui pengaruh perubahan desain ruang operasi dan perilaku petugas di ruang operasi terhadap kejadian SSI di RS Santa Maria Pemalang dan mencari faktor risiko SSI.

**Metode:** Jenis penelitian yang digunakan kuasi eksperimental dengan rancangan penelitian *pre* dan *post test* tanpa kontrol grup. Populasi penelitian ini adalah semua petugas ruang operasi sedangkan subyek penelitian ini adalah desain ruang operasi. Variabel dependen pada penelitian ini adalah angka kejadian SSI sedangkan variabel

independennya berupa perilaku petugas di ruang operasi dan desain ruang operasi. Instrumen pengumpulan data menggunakan *check list* untuk *pre* dan *post test*. Pengolahan data menggunakan uji analisis *independent t test*, *chi square* dan analisis multivarian *logistic regression*.

**Hasil penelitian** : Perubahan desain ruang operasi dan perubahan perilaku petugas di ruang operasi terbukti secara bermakna menurunkan angka kejadian SSI (OR= 3,646; CI<sub>95</sub> 1,24 < OR < 10,77).

**Kesimpulan** : Intervensi yang diberikan terhadap desain dan perilaku petugas dapat menurunkan angka kejadian SSI. Faktor resiko SSI adalah desain ruang operasi, perilaku petugas di ruang operasi dan lama operasi.

## INTRODUCTION

Data on the mortality rate caused by medical error collected by The Institute of Medicine (IOM) is rather alarming. Mortality rate caused by medical error is far higher than that caused by traffic accident and breast cancer. Medical error results in various medical and non-medical outcomes, such as prolongation of length of stay, loss of income, additional high cost of medical care, reversible mild disability to permanent disability, and death.<sup>1</sup>

World Health Organization (WHO) estimates that the case rate caused by medical error and adverse events in several developing countries is not low<sup>1</sup>. This condition is suspected by WHO to be caused by poor infrastructure and health care facility, drug limitation, minimum preventive and infection control measures, poor performance of health care staff, dysfunctional medical appliances, and obsolete medical technology<sup>2</sup>.

Nosocomial infection occurred in health care is one of the adverse events. There are 4 types of nosocomial infections, that is: urinary tract infection, surgical site infection (SSI), septicemia, and pneumonia.<sup>3</sup> WHO also reported the incidence of SSI was between 2-5% in 27 million patients who had surgeries each year. The infection rate in health service facility was sufficiently high, that is 25%.<sup>2</sup>

Mangram *et al.* (1999) classified SSI, based on its depth and the involvement of organs, into 3 types, that is superficial incisional SSI, deep incisional SSI, and organ/space SSI. Based on its etiology there were 2 factors: surgery and patients.<sup>4</sup>

In Santa Maria Hospital Pematang, there were 7 cases of SSI in 2005 and 2006, but the number was considered as the tip of iceberg of all SSI cases. It was caused by false understanding of the clinicians on the criteria of SSI made by Mangram *et al.* Besides, SSI was assumed to be caused by the behavior of staff/team/nurses in operating room and the design of operating room of Santa Maria Hospital

Pematang, which was not agreeable with standard by KepMenKes No: 1204/MENKES/SK/X/2004 on Requirement of environmental physical health in the hospital.

The aim of this study was to find out the effect of the change in operating room design and operating room staff behavior on the incidence of SSI in Santa Maria Hospital Pematang in 2007.

## METHOD

It was a quasi-experimental study, with pre-posttest without control group design. Population of the study was all operating room staff, while subjects of the study were operating rooms and staff who worked in them. The independent variables were the design of operating rooms and the behavior of the staff, while the dependent variable was the incidence of SSI. Instruments used were SSI checklist, design of operating room checklist, and staff behavior checklist. Data were collected by observing the design of operating rooms, staff behavior, and SSI. SSI data were also collected by documenting surgical ulcer since patients leaving operating room until 30 days post surgery by visiting the patients' houses. Intervention on the design were the change of operating room design, and adding the instruments and facilities in operating room. Intervention on behavior was conducted by exposing the concept of patient safety in operating room and creating SOP. Data analysis used were 2 independent sample t-test and chi-square test, followed by multivariate logistic regression.

## RESULT

In this study, there were two interventions: intervention on the design of operating rooms and intervention on staff behavior in operating rooms. Interventions on the design of operating rooms were:

closing the ventilation opening, constructing hole to sterilization room, constructing the disposal slot of dirty utensils in operating room, redesigning the zoning in operating rooms, changing the entrance and exit tracks for patients, operators and his teams, changing the dirty instrument track, constructing HEPA filter, central AC and positive pressure in operating room, and installing UV lamp. Interventions conducted on behavior were: distributing the concept of safety on operating room, and creating implementing SOP for operating room.

In this study, there's also several stages conducted out of plan, i.e. installation of HEPA filter, identification of microorganism, and resistance test. Besides, in several meeting with the institution, directors, operators and nurses, there were in-depth discussions on instrument procurement, the change in operating room design, and implementation of SOP and SSI criteria. The discussions end well with the agreement of all parties in supporting patient safety in Santa Maria Hospital Pematang.

TABLE 1. Result of investigation of air, lighting, temperature, and noise index in operating room of Santa Maria Hospital Pematang in 2007

No	Parameters measured	Result				Regulated maximum level
		Pre-Intervention		Post-Intervention		
		OR 1	OR 2	OR 1	OR 2	
1	Microorganism index	670 CFU/m <sup>3</sup>	670 CFU/m <sup>3</sup>	521.000 CFU/m <sup>3</sup>	1.300 CFU/m <sup>3</sup>	10 CFU/m <sup>3</sup>
2	Lighting index	267 lux	250 lux	138 lux	309 lux	300 – 500 lux
3	Temperature	26°C	26°C	27°C	26°C	19 - 24°C
4	Humidity	77 %	84 %	77 %	78 %	45 – 60 %
5	Pressure	Negative	Negative	Positive	Positive	Positive
6	Noise Index	54,3 db	51,9 db	49,2 db	62,7 db	45 db

Result of parameters measured by BBTKL Yogyakarta between pre-intervention and post-intervention showed that there was no improvement. Microorganism index in OR 1 was very high compared with the standard from DepKes RI. In the investigation of lighting index, all available lamps in operating room were not turned on, particularly the lamps over the operating table, so that this result was substandard. Meanwhile, in post-intervention investigation of lighting index in OR 2, the result was agreeable with the standard, because the timing of the measurement was in the middle of surgery in the operating room.

Researcher also identify the microorganism, while sensitivity test was conducted by Balai Laboratorium Kesehatan Yogyakarta (BLK). TABLE 2 shows that the types of microorganism identified were variable, while sensitivity test result showed resistant microorganisms to several antibiotics, the antibiotics were still used in Santa Maria Hospital Pematang in postsurgical cases, and this could affect the incidence of SSI.

TABLE 2. Result of Identification of Microorganisms in Operating Rooms of Santa Maria Hospital Pernalang in 2007

No	Microorganism	Result of sensitivity test								
		A	B	C	D	E	F	G	H	I
1	<i>Pseudomonas aeruginosa</i>	R	S	S	R	R	R	R	S	S
2	<i>Staphylococcus aureus</i>	S	S	S	S	S	S	S	S	S
3	<i>Eschereshia coli</i>	S	S	S	S	S	S	S	S	S
4	<i>Enterobacter aeruginosa</i>	S	S	S	S	R	S	R	S	S
5	<i>Bacillus subtilis</i>	R	S	S	S	R	I	R	S	S
6	<i>Bacillus cereus</i>	R	R	I	R	R	R	R	S	S

Note:

- |                                 |                               |
|---------------------------------|-------------------------------|
| A : Ampicilline-clavulanic acid | G : Ampicilline-sulbactam     |
| B : Kanamycine                  | H : Imipenem                  |
| C : Amikacine                   | I : Ciprofloxacine            |
| D : Ceftriaxone                 | R : Resistant                 |
| E : Cefoxitin                   | S : Sensitive                 |
| F : Cefotaxime                  | I <sup>1</sup> : Intermediate |

TABLE 3. Result of Observation on Operating Rooms in Santa Maria Hospital Pernalang in 2007

No	Observed aspect	Pra-Intervention (score)				Post-Intervention (score)				% Average Increase
		Min	Max	Avg	Std	Min	Max	Avg	Std	
1	Physical design of operating room	7	7	7	0	8	9	8.3	0.5	18.6
2	Circulation of operating room staff	6	6	6	0	8	8	8	0	33.3
3	Circulation of patients	4	4	4	0	7	7	7	0	75
4	Circulation of clean/sterile instruments	2	2	2	0	2	3	2.3	0.5	15
5	Circulation of non-sterile instruments	1	1	1	0	1	3	2	1	100
6	Non-physical requirement of operating room	5	5	5	0	6	10	7.3	1.9	46
7	SOP	3	3	3	0	6	6	6	0	200
8	Indicator agreeable with the DepKes RI requirements	0	0	0	0	1	1	1	0	100

TABLE 3 shows scores acquired from checklist of operating room design. Researcher compared the results of pre-intervention and post-intervention on the design of operating room, and the parameters

assessed were increased. The increase caused the discrepancy between operating room standard by DepKes and operating room in Santa Maria Hospital Pernalang to be smaller.

TABLE 4. Result of Observation on Operating Room Staff of Santa Maria Hospital Peralang in 2007

No	Observed aspects	Pra-Intervention (score)				Post-Intervention (score)				% Average Increase
		Min	Max	Avg	Std	Min	Max	Avg	Std	
1	Wash hands according to procedure	23	28	26	1	32	32	32	0	23
2	Wear operating gown	8	8	8	0	8	8	8	0	0
3	Wear gloves	4	8	6	1	6	8	8	0	33.3
4	Wear other protective attire	8	12	8	1	9	13	11	1	37.5
5	Help the execution of surgery directly	24	24	24	0	24	24	24	0	0
6	Close surgical wound	12	12	12	0	12	12	12	0	0
7	Take off gloves according to procedure	3	4	4	0	4	4	4	0	0
8	Change operating gown, mask, cap, apron, gloves for next surgery	1	4	3	1	3	4	4	0	33.3

Result of observation on operating room staff pre-and post-intervention was shown in TABLE 4. Eight aspects observed by researchers, and from the eight aspects, the increase was only occurred in 4 aspects scores. Percentage of average increase was variable, from 23-37.5%. Obstacles met in the implementation of SOP was caused by the lack of staff self-protective attire, so that the score didn't reach the maximum score.

Characteristics of subjects observed in this study was shown in TABLE 5. Generally, characteristics

of subjects in both groups, i.e. pre- and post-intervention, was relatively similar in proportion based on gender, age, type of room, type of disease, and those related to surgery, such as the type of surgery, duration of care before surgery, duration of surgery, and concomitant disease.

Observation of SSI incidence was shown in TABLE 6. Most SSI occurred in the third day (pre-intervention 85.6% and post-intervention). TABLE 6 also shows that Obsgyn Unit was one of the risk factors of SSI.

TABLE 5. Characteristics of Patients Operated in Santa Maria Hospital Pematang in 2007

Patient Characteristics	Pra- Intervention Total (%)	Post- Intervention Total (%)
<b>Gender</b>		
• Man	15 (34)	14 (25.9)
• Woman	29 (66)	40 (74.1)
<b>Age</b>		
• < 30 years old	22 (50)	28 (51.8)
• ≥30 years old	22 (50)	26 (48.2)
<b>Type of Room</b>		
• Mawar	2 (4.5)	5 (9.3)
• Anggrek	23 (52.3)	27 (50.0)
• Melati	19 (43.2)	22 (40.7)
<b>Type of Disease</b>		
• Surgery	22 (50)	29 (53.7)
• Obsgyn	22 (50)	25 (46.3)
<b>Type of Surgery</b>		
• Elective	28 (63.6)	37 (68.5)
• Cito	16 (36.4)	17 (31.5)
<b>Duration of Care Before Surgery</b>		
• ≤1 day	36 (81.8)	43 (79.6)
• > 1 day	8 (18.2)	11 (20.4)
<b>Duration of Surgery</b>		
• < 55 minutes	20 (45.5)	22 (40.7)
• ≥55 minutes	24 (54.5)	32 (59.3)
<b>Concomitant Disease</b>		
• Early rupture of the membrane	5 (11.4)	3 (5.6)
• KP	1 (2.3)	2 (3.7)
• Open fracture	0	2 (3.7)
• Anemia	0	2 (3.7)
• No concomitant diseases	38 (86.3)	45 (83.3)

TABLE 6. Result of SSI Observed in Santa Maria Hospital Pematang during the Study

SSI	Pre Intervensi Jumlah (%)	Post Intervensi Jumlah (%)
<b>Incidence of SSI</b>		
• SSI	21 (47.7)	14 (25.9)
• No SSI	23 (52.3)	40 (74.1)
<b>SSI</b>		
• Surgery	4 (19)	3 (21.4)
• Obsgyn	17 (81)	11 (78.6)
<b>Timing of SSI</b>		
• 3 days	18 (85.6)	6 (42.8)
• 5 days	1 (4.8)	4 (28.5)
• 7 days		1 (7.1)
• Home visite	1 (4.8)	4 (21.6)
	1 (4.8)	

Interrelation between risk factors and incidence of SSI can be described by multivariate logistic regression analysis. TABLE 7 shows that intervention and duration of surgery were risk factors of the

incidence of SSI. Other variables such as health service unit, type of room, type of surgery, and concomitant disease were not the risk factors of SSI.

TABLE 7. Logistic regression analysis of several variables affecting the incidence of surgical site infection in Santa Maria Pemalang in 2007

Variable	Chi square analysis		Multivariate analysis	
	Crude OR	CI	Adjusted OR	CI
Intervention				
• Pra-intervention	2.48	1.05 – 5.81	3.646	1.24 – 10.77
• Post-intervention				
Health Service Unit				
• Obsgyn	9.21	3.4 – 24.96	742173708.68	0.00 – .....
• Surgery				
Type of Room				
• Anggrek	7.62	2.85 – 20.3	0.00	0.00 – .....
• Mawar/Melati				
Type of Surgery				
• Cito	3.98	1.63 – 9.74	0.92	0.22 – 3.86
• Elective				
Concomitant Disease				
• No	3.17	1.02 – 9.85	2.45	0.64 – 9.12
• Yes				
Duration of surgery				
• = 55 minutes	6.96	2.51 – 19.2	3.67	1.04 – 12.90
• < 55 minutes				

## DISCUSSION

Kepmenkes No. 1204/MENKES/SK/X/2004 on Hospital Environment Health<sup>5</sup> required that all physical requirements in operating room of Santa Maria Hospital Pemalang has satisfied most of required criteria by Kepmenkes after interventions were conducted. However, they haven't satisfied non-physical requirements. Several indicators not fulfilled were: microorganism rate index, lighting index, temperature, humidity, and noise index. From several indicators, there was one point to be noted, that is the higher index of microorganism rate after intervention compared with that before intervention. Kunders<sup>6</sup> and Health Department of Western Australia<sup>7</sup> also suggested operating room requirements in the terms of quantity and type of room that have to be available, air scrub up water flow facility, 4 main tracks available in operating room: patient track, operator track, clean instrument track, dirty instrument track, and requirement of wall and

floor inside the operating room which not to be allowed to have gaps. If operating rooms in Santa Maria Hospital Pemalang were compared with the requirement of Kunders and Health Department of Western Australia, there were still a discrepancy. Other study by Triatmojo<sup>8</sup> also mentioned that 4 of 6 hospitals studied had higher microorganism rate compared with the upper limit allowed by Depkes. Many factors causing the high rate of microorganism rate, among others, sterilization of operating room by fogging was not conducted, traffic line of staff and patients entering operating room were not restricted, control of operating room staff health condition, sterilization procedure of operating room was not conducted properly, ventilation system of operating room was not maintained properly, and septic and aseptic operating rooms were not separated.<sup>9</sup>

Result of identification of types of microorganism and resistance test conducted in operating rooms showed that there were 6 types of

microorganism, among others *Staphylococcus aureus*. Other study by Triatmojo<sup>8</sup> also found similar microorganisms to those found in Santa Maria Hospital Pemalang. It was found in 4 of 6 hospitals whose operating rooms were studied. Other study by Suparno<sup>10</sup> found 10 types of microorganisms identified as the cause of surgical wound infections in Obstetry Unit Dr. Sardjito Hospital Yogyakarta. From those 10 types, 3 of them were also identified in Santa Maria Hospital Pemalang, i.e. *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Enterobacter aeruginosa*. Resistance test conducted also showed several types of microorganisms which were resistant to cefotaxime, while this antibiotic is the most widely used in Santa Maria Hospital Pemalang. The resistance to microorganism also caused antibiotic used to be ineffective, so that it might affect the incidence of SSI. Based on this condition, culture examination is needed for identification and resistance test of materials are derived from pus acquired from SSI wound.

TABLE 4 shows the increase in staff compliance to SOP, as shown by the increase in staff score after the intervention. The increase was variable, from 23-37.5%. Compliance in implementing SOP was hindered by the limited instruments and facilities in operating rooms, for example, surgical glasses. Creating SOP for operating rooms is one of the applied actions of clinical risk management and evidence based practice, which is a component of clinical governance.

Report from World Alliance for Patient Safety<sup>2</sup> mentioned SSI rate was between 2% to 5%, while other study by Health Protection Agency<sup>11</sup> showed SSI rate between 1.7-15.6%, depended on the type of surgery. In this study, there were 21 patients (pre-intervention) who suffered from surgical site infection (SSI) of 44 patients who had surgeries. This number is relatively high (47.7%), while in post-intervention, the SSI rate decreased to 25.9% of 52 patients who had surgeries. Compared to several aforementioned studies, SSI in Santa Maria Hospital Pemalang was classified as high. The rate was a lot higher than data in medical records, where in 2005 and 2006, there were only 6 cases of SSI for 1 year. The big difference in these incidences of SSI could be caused by the difference in perception of SSI criteria used by researchers. Researcher used

SSI criteria based on study of Mangram *et al.*,<sup>4</sup> in his article titled "Guideline for prevention of surgical site infection: infection control and hospital epidemiology". Meanwhile, criteria used by surgeon and obstetrician in Santa Maria Hospital was very different, where they considered the diagnosis was SSI if there was pus and/or surgical wound with dehiscence.

SSI cases in Santa Maria Hospital were also unique, where SSI was mostly occurred in Obsgyn Unit, which was 81% at pre-intervention and 78.6% at post-intervention (TABLE 6). Other study by Health Protection Agency<sup>11</sup> showed that SSI cases in gynecology unit was 2.4%, while Yokoe<sup>12</sup> found SSI in 5% of cesarean section. The difference in these SSI rates was so big in Santa Maria Hospital Pemalang compared with other studies in several countries, because of difference in perception of SSI criteria used.

Several risk factors of SSI in Santa Maria Hospital Pemalang were identified, i.e., intervention and duration of surgery. This is supported by a study by Killian *et al.*<sup>13</sup> who found that the duration of surgery, prophylaxis antibiotics, prenatal visit > 7 times, duration of early rupture of the membrane were risk factors of SSI in cesarean section. Study by Razavi *et al.*<sup>14</sup> found several risk factors related to incidence of SSI in abdominal surgery, such as the duration of care after surgery, type of surgery (cito or elective), duration of surgery, time of shaving, and type of incision. Meanwhile, Suparno<sup>7</sup> found risk factors of SSI in Gynecology Unit Dr. Sardjito Hospital Yogyakarta, i.e., age > 45 years old, Hb level < 11 g%, qualification of operator, and emergency level of surgery. Study by Mitt *et al.*<sup>15</sup> found SSI rate after patients were discharged was 42.1% of SSI found during period of the study. SSI rate was higher compared with that in home visit by the researcher, i.e., 4.8% in pre-intervention observational period and 21.6% in post-intervention observational period (TABLE 6). Based on timing of SSI, most SSI occurred in the third day was 85.6% in pre-intervention observational period, while in post-intervention period it was decreased to 42.8%. Based on researcher opinion, SSI occurred in the third day was caused by actions in operating room. This might occurred because the surgical wound was dressed and treated in the patient ward on the



third day. It was proven after intervention that SSI rate in the third day decreased to 42.8%. While SSI after the third day until the seventh day in pre-intervention period was 9.16%, but in observation after intervention, there was 26.44% increase. It showed that wound care in the patient ward could also be the risk factor of SSI. The factors were the sterility of the ward, and behavior of nurses in the ward when they conducted the wound care.

TABLE 7 shows risk factors most related to the incidence of SSI in Santa Maria Hospital Pemalang by conducting multivariate logistic regression analysis. They were the intervention and duration of surgery. This is supported by study by Kasatpibal *et al.*<sup>15</sup> where duration of surgery >1 hour had higher risk to cause SSI. Cruse and Foord in 1980 (cit Tietjen *et al.*<sup>16</sup>) mentioned that the longer the duration of surgery, the higher the risk of SSI. SSI incidence was doubled for each hour of surgery. Razavi<sup>14</sup> found that the duration of surgery  $\geq 2.24$  hours had higher risk of SSI. This study found the duration of surgery of  $\geq 55$  minutes could increase the risk of SSI 3.67 times (OR = 3.67, 95%CI = 1.04-12.09). It was agreeable with the study by Kasatpibal *et al.* and Cruse and Foord in 1980 (cit Tietjen *et al.*)<sup>15,16</sup>.

## CONCLUSION AND SUGGESTION

### A. Conclusion

Change in the operating room design and staff/nurse behavior in operating room was proven to be significantly decrease the incidence rate of SSI in Santa Maria Hospital Pemalang.

Risk factors of SSI identified in Santa Maria Hospital Pemalang were the design of operating rooms, behavior of staff/nurse in operating room, and the duration of surgery.

### B. Suggestion

It is suggested to the management of Santa Maria Hospital Pemalang to conduct sterilization method with disinfectant fogging, separate the septic and aseptic operating rooms, evaluate regularly the indicators required by SK Menkes in operating room and ward with good preparation, conduct culture, identify the type of microorganism, and regular

resistance test from air samples and from pus excreted by SSI. Clinical governance through clinical audit is needed, beginning with cases most often causes SSI, change the therapeutic standard used according to evidence based and pay attention to the result of resistance test, and conducting wound care according to evidence based wound management.

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