http://dx.doi.org/10.15682/jkiha.2016.22.3.27

A Study on the Development of Predictive Model for Patient Visibility in Korean Intensive Care Units (ICUs)
- Focused on "Corridor or Continental" type units

Ullah, Ubaid* 울라 우바이드 | Park, Jae Seung** 박재승

Abstract

Purpose: The purpose of this paper is to develop a predictive model for patient visibility in Korean ICUs (corridor or continental type). **Methods**: The measures of static visibility were used to quantify the patient visibility (upper third part of the patient bed) from the nurse station. The measure of space programme and area distribution (patient zone percentage, staff zone percentage and departmental gross square meter per patient bed) were calculated by using AutoCAD and MS Excel programs. Regression analysis was conducted for visibility as dependant variable with independent variables of patient area percentage, staff area percentage as well as departmental gross square meter per bed by using IBM SPSS. Results: (1) Average patient visibility and percentage of patient area in ICU shows a strong negative correlation (r^2=0.66), p=0.01. (2) Patient visibility in Korean ICU (corridor or continental type) can be calculated as below with the given conditions: Y= -1.449(X)+124.3±6, Y is the total visibility of the ICU (corridor or continental type) and X is the percentage of patient area in the unit. Conditions:1. Given that the unit has a mixed programme of open bed and closed patient rooms and 2. The unit have a minimum of 20% patient rooms. **Implications**: This study may contribute to the visibility analysis of existing and future ICU design (corridor or continental type) in Korea to achieve maximum patient visibility and reduced patient mortality.

Keyword Intensive care unit, Critical care Unit, Predictive model of patient visibility, Visual surveillance, Patient mortality, ICU planning and design.

1. Introduction

1.1 Background and Purpose

In a multicenter retrospective analysis of 1090 Korean ICU patients by Kang et al. (2009) from 18 hospitals with 500-2,200 beds, the overall mortality rate was 24.1%, which is higher than the developed countries (U.S. 10%, UK 18% and Spain 21%).[1) Although there are multiple factors associated with patient mortality in ICU, which can be categorized as related to staff, equipment, medication, and timing or any combination of them.

If we further analyze the above factors, design and layout of the ICU affect them all in one or the other way. For instance,

Optimal patient visibility from nursing stations has long been a significant design consideration for ICUs. Indeed, the Society of Critical Care Medicine design guidelines suggests direct visualization at all times with a preference for a line of sight between the patient and central nurse station.[2)]. It is inferred that patient visibility affects clinical outcomes until 2010, however, no evidence existed that this was the case. The study,

* Member, PhD. Candidate Department of Architecture, Graduate School of Hanyang University (Primary author: ubaid123@hanyang.ac.kr)

** Honorary President, Professor, PhD. Department of Architecture, Hanyang University (Corresponding Author: jaespark@hanyang.ac.kr)

1) Kang, ChulHwan, et al.(2009) "The variation in risk adjusted mortality of intensive care units." Korean Journal of Anesthesiology 57.no.6. pp: 698-703.

2) Society of Critical Care Medicine, 1995. Guidelines for intensive care unit design. Crit Care Med.23. Pp. 582–588.

titled "Relationship between ICU Design and Mortality" (Leaf, Homel & Factor, 2010), was the first to implicate patient visibility, defined as seen or unseen from the central nurse station, as a factor influencing patient mortality.

In all ICU designs, nurses remain vigilant about their ability to see and access patients.

In light of the above, the purpose of this study is to analyze a sample of Korean ICUs in terms of patient visibility and its relationship with the space programme and area distribution.

1.2 Objectives of the Study

First to examine patient visibility in a sample of "corridor or continental" type Korean ICUs from across the country to explore its correlation with design factors.

Secondly to produce a baseline data and method for the design of future ICUs with maximum visibility from the nurse station.

2. Literature Review

2.1 An overview of ICU

1) Definition of ICU

"Intensive care units (ICU), also called critical care or intensive therapy departments, are sections within a hospital that look after patients whose conditions are life-threatening and need constant, close monitoring and support from equipment and medication to keep normal body functions going."[3)]

They have higher levels of staffing, specialist monitoring and treatment equipment only available in these areas and the staff are highly trained in caring for the most severely ill patients. Hospitals differ in what they call these areas but their role and expertise are the same.

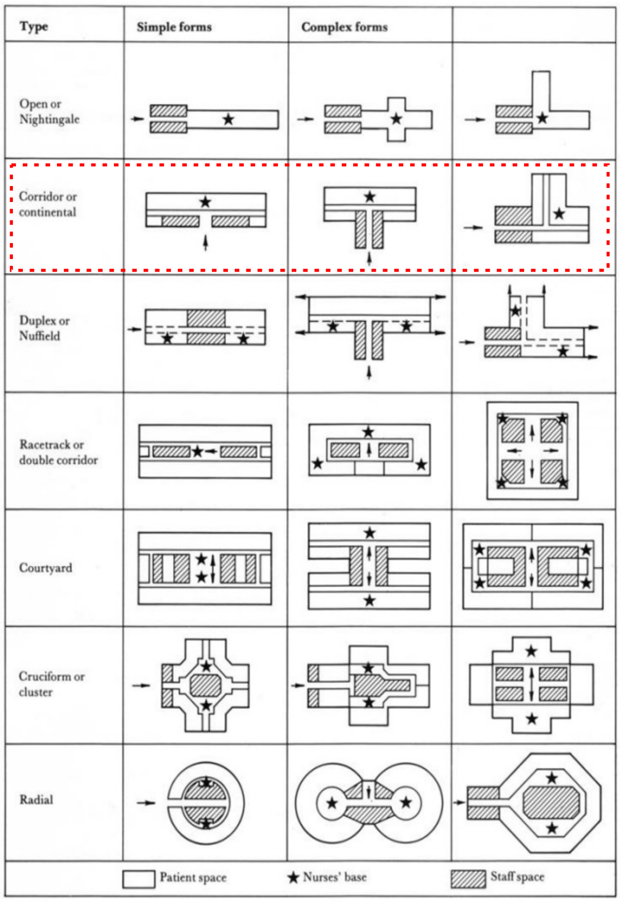
2) Functional Type of ICU

A typology of adult ICUs often includes the following medical specialties: medical ICU, surgical ICU, neurological ICU, coronary care unit (CCU), respiratory ICU, burn ICU, and mixed service ICU.

3) Layout Type of ICU

ICUs, like any other hospital inpatient units, can be designed to have different layouts. Among the more commonly used layouts are racetrack layout, single- or double-corridor layout, open-plan layout, radial layout and some combinations.

James and Tatton-Brown (1986) proposed the following nursing unit typologies.[4)] The focus of this study is the second type that is "corridor or continental" type unit.



[Figure 1] Nursing unit typologies. Source: James and Tatton-Brown, 1996, p.76

2.2 Patient Visibility in ICU

1) Introduction

The fundamental design of the 19th century nursing unit layout was an open floor plan with as many as thirty-six patient beds in one rectangular room or unit. In 1863, Florence Nightingale described the design element of visibility as essential to nursing efficacy, stressing the importance of positioning a nursing station in the unit to ensure a view of the entire room both during daytime and at night.[5)]

3) "What is Intensive Care?" http://www.ics.ac.uk/icf/patients-and-relatives/information/about-critical-care/what-is-intensive-care/,Intensive Care Society UK, 2016.04.14.

4) James, W. P., & Tatton-Brown, W. (1986). Hospitals: design and development: Architectural Press.

5) Nightingale, Florence 1863. Notes on hospitals. Longman, Green, Longman, Roberts, and Green.

2) Quantifying Patient visibility

Leaf et al.(2010), divided the rooms into low visibility versus high visibility room. The low visibility rooms were defined as those in which an observer from anywhere in the central nursing station could not see any part of the patient and vice versa the high visibility room.

Lu et al. (2014) had developed several measures to quantify room visibility and patient's head visibility and so on.[6)]

Their method of room visibility is based on dividing the patient room into one by one feet grid and connecting them all to not only the nurse station area but also nurse counter. The average nurse station area which can see these points is termed as the room visibility.

As opposed to the above quantification methods, Catrambone et al. (2009), measured visibility as "by standing at each nurse charting area (station) and counting the beds that met the criteria that the upper third of the bed could be seen when either the door or room blinds were opened. This definition was selected because the ability to see the head, hands, and chest is a key to cue for nursing action in the event of respiratory distress and unsafe acts."[7)]

Therefore, the method to quantify the patient's visibility (upper third part of the bed) from the nurse counter (not the whole area of nurse station) is employed in this study.

2.3 An overview of Korean ICU

In 1962, two university hospitals in Korea set up ICUs as postoperative respiratory care units. Since then, the number of ICUs has continued to increase. When the Korean Society of Critical Care Medicine (KSCCM) was organized in 1980, 18 university hospitals and nine general hospitals had ICUs.

Compared with other medical fields, the quality of critical care has lagged behind that of advanced countries. Moreover, the level of critical care quality differs significantly between university hospital ICUs[8)].

At present, there are 657 ICUs (Table 1).

[Table 1] Number and percentage of ICUs in Korea

Classification of Healthcare Facility	No. of ICUs
Tertiary Hospital	259 (29.2%)
General Hospital	426 (48%)
Hospital	162 (18.3%)
Long-Term Care Hospital	12 (1.4%)
Clinic	8 (0.9%)
Health Center & Country Hospitals	2 (0.2%)
Korean Medicine Hospital	4 (0.5%)
Korean Medicine Clinic	4 (0.5%)
Armed Forces Hospital	10 (1.1%)
Total	657 (100%)

Source : Medical Korea Statistics.[9)]

1) A Comparison of Space Programme and Area Distribution of Korean and US Cases

① ICU. bed Ratio in the hospital:

In the Korean Hospital, ICU. beds are 5-8% of the total inpatient beds, while in the US, this ratio is 10-20% of total inpatient beds.[10)]

② Departmental Area per Bed:

In the Korean Hospital, the area per ICU. beds ranges from 30-52 m^2/bed, while in the US, the area per bed ranges from 84-97 m^2/bed.

③ Gross Factor:

In the Korean Hospital ICU. the gross factor range from 1.31-1.51, while in the US, the gross factor range from 1.34-1.96.[11)]

3. Method

3.1 Overview of the Cases

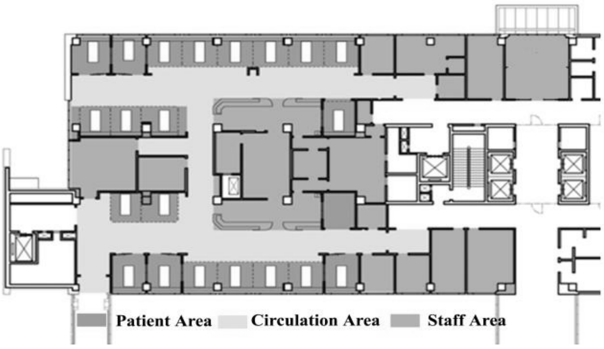
Eight cases of "corridor or continental" plan type ICUs were selected for the analysis from five Korean hospitals. In most of the case, two samples were taken from same hospital with generally same layout, but of differing patient visibility and area distribution as well as patient capacity.

6) Lu, Yi, et al. (2014) "Patient visibility and ICU mortality: A conceptual replication." HERD: Health Environments Research & Design Journal 7, no. 2 Pp: 92-103.
7) Catrambone, Cathy, et al.(2009) "The design of adult acute care units in US hospitals." Journal of Nursing Scholarship 41, no.1. Pp: 79-86.
8) Lim, Chae-Man, et al.(2015) "Critical Care In Korea: Present and Future." Journal of Korean medical science 30, no.11 Pp: 1540-1544.

9) "The Number of Delivery Rooms, Infant Units, Operating Rooms, Emergency Rooms, Intensive Care Units" http://www.medicalkorea.or.kr/content.do?method=getContent&gcd=G1001&cmscd=CM9015, Medical Korea Statistics, 2016.04.14
10) Cadenhead, C., and D. Anderson. (2010) "Critical care design: Trends in award winning designs." World Health Design 2, Pp: 72-77.
11) Allison D, Hamilton DK. 2008."Analysis of department area in contemporary hospitals: Calculation methodologies & design factors in major patient care departments". Funded in part by the American Institute of Architects' Academy of Architecture for Health Foundation; 2008.

1) Case-1: B.N.U. Hospital Double ICU

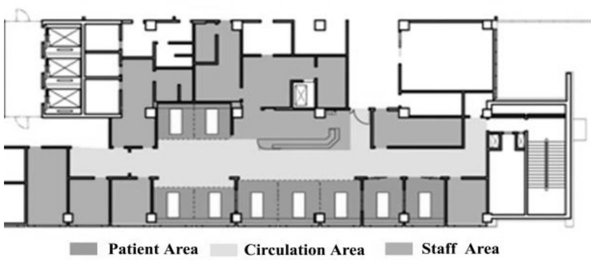
B.N.U. Hospital has 43 beds (5.5%) in ICUs out of 770beds total. There are 12 beds in 1st ICU, 10 beds in 2nd ICU. The first and second ICU is connected having combined central nursing space. The area per bed is 45.68m²/bed and the gross factor is 1.42.



[Figure 2] B.N.U. Hospital (1st& 2nd ICU- 2nd Floor)

2) Case-2: B.N.U. Hospital Single ICU

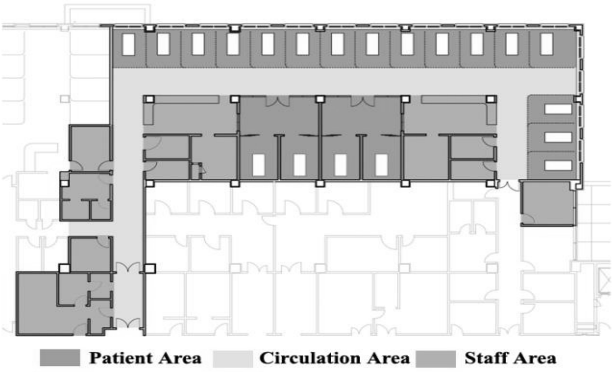
B.N.U. Hospital has 43 beds (5.5%) in ICUs out of 770beds total. There are nine beds in 3rd ICU. The area per bed is 46.73m²/bed and the gross factor is 1.35.



[Figure 3] B.N.U. Hospital (Single ICU-2nd Floor)

3) Case-3: D.K.U. Hospital MICU

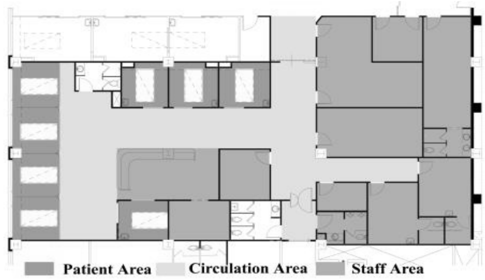
Opened in June 2005, D.K.U. Hospital has 800 hospital beds in 92561.98 m² total floor area. There are 60 (7.5%) ICU beds in total. There are 20 beds in MICU, 20 in SICU+NSICU ,eighteen CCU, and 12 in Oriental Medicine ICU. The area per bed 34.20m²/bed and the gross factor is 1.36.



[Figure 4] D.K.U. Hospital (MICU-2nd Floor)

4) Case-4: S.N.U. Hospital CCU

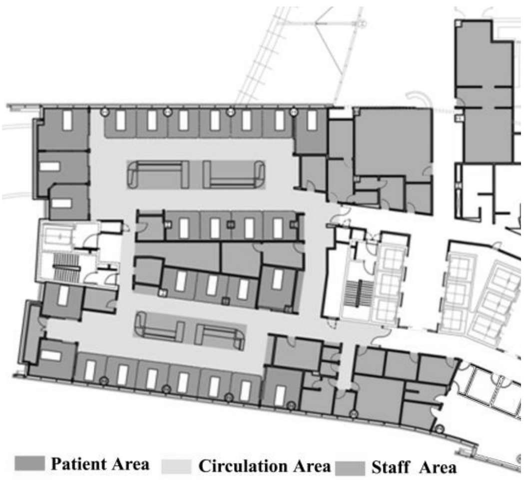
S.N.U. Hospital opened in 2003 with total floor area of 128022.20 m². there are 8 beds in CCU, 16 in MICU and 20 in RCU/SICU. The area per bed 45.50m²/bed and the gross factor is 1.48.



[Figure 5] S.N.U. Hospital (CCU-2nd Floor)

5) Case-5: S.C. Hospital, MICU

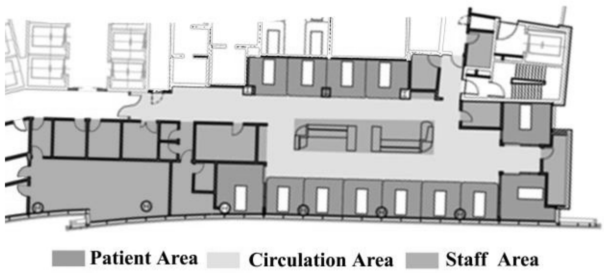
S.C. Hospital with 700 beds has 40 (5.7%) direct-view ICU beds. There are 127 beds in MICU(2). The area per bed is 46.82㎡/bed and the gross factor is 1.51.



[Figure 6] S.C. Hospital (MICU-3rd Floor)

6) Case-6: S.C. Hospital, SICU

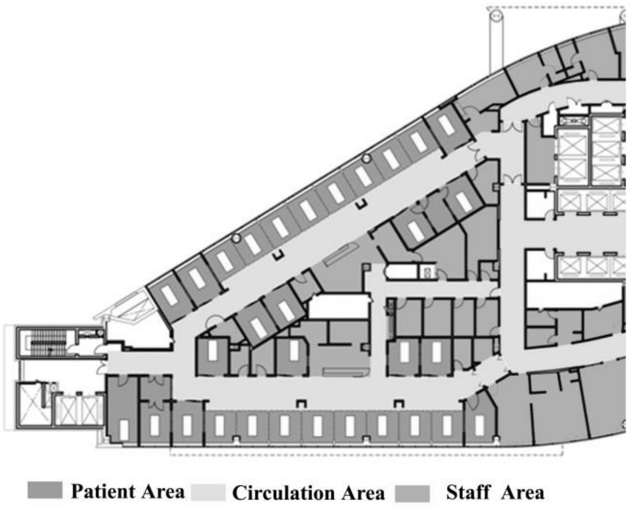
S.C. Hospital with 700 beds has 40 (5.7%) direct-view ICU beds. There are 13 beds in SICU. The area per bed is 51.55㎡ /bed and the gross factor is 1.51.



[Figure 7] S.C. Hospital (SICU-3rd Floor)

7) Case-7: New Y.S. Hospital MICU

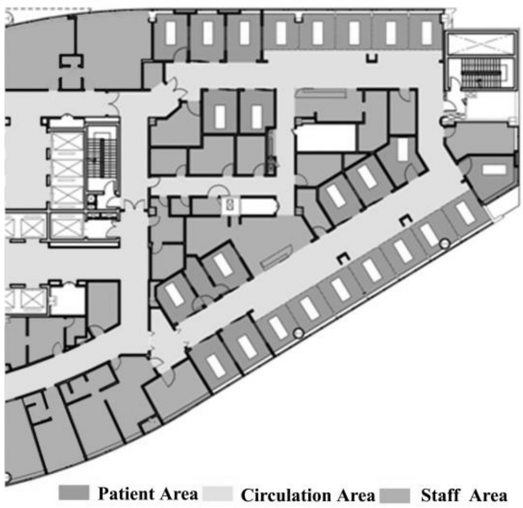
New Y.S. Hospital opened in 2005. The total number of beds is 1,000 and the 75 (7.5%) ICU beds are direct-view type. There are 31 beds in MICU(2 units). The area per bed is 41.61㎡/bed and the gross factor is 1.45.



[Figure 8] New Y.S. Hospital (MICU-9th Floor)

8) Case-8: New Y.S. Hospital MICU & SICU

New Y.S. Hospital opened in 2005. The total number of beds is 1,000 and the 75 (7.5%) ICU beds are direct-view type. There are 25 beds in MICU+SICU (2 units),The area per bed is 46.79㎡/bed and the gross factor is 1.43.



[Figure 9] New Y.S. Hospital (MICU+SICU-9th Floor)

3.2 Materials and procedures

The following aspects of area distribution, space programme and visibility were calculated using the following softwares.

① Area Distribution of ICU that is, Patient zone, staff zone, and circulation zone were calculated using Auto CAD and MS Excel.

② Space programme, which includes the departmental gross square meter (DGSM) per bed, gross factor and number of beds in the unit were calculated using Auto CAD and MS Excel.

③ Patient visibility (upper third part of the bed) was calculated using Auto CAD and MS Excel.

④ Correlation was calculated between patient visibility and area distribution, DGSM/bed, the number of beds in the unit etc. using SPSS.

4. Analysis of the Cases

The analysis of the cases was started from the calculation of space programme and area distribution using AutoCAD and MS Excel software. In the next step, the measures of patient visibility were calculated. The following account gives a step by step procedure and findings from the analysis.

4.1. Calculation of Space Programme

In the first step of the analysis, the space programme of each unit was calculated using AutoCAD. and Ms Excel program. Departmental Gross Square Meter (DGSM) per bed was calculated for each unit. The gross factor was also calculated for each unit (Table 2).

4.2. Calculation of Departmental Area Distribution

In the second step of the analysis, the area distribution in each unit was calculated using AutoCAD. and Ms Excel program. each department was broken down into the following three components.

[Table 2] Summary of Space Programme & Area Distribution

Case No.	Area Per Bed	Gross Factor	Patient Area	Circulation Area	Staff Area
01	45.6m²/bed	1.42	25.41%	29.70%	44.88%
02	46.6m²/bed	1.35	23.85%	26.07%	50.08%
03	34.2m²/bed	1.36	40.44%	26.73%	32.84%
04	45.5m²/bed	1.48	22.89%	32.43%	44.67%
05	46.8m²/bed	1.51	27.43%	33.97%	38.60%
06	51.5m²/bed	1.51	29.89%	33.80%	36.31%
07	41.6m²/bed	1.45	33.47%	30.93%	35.60%
08	46.7m²/bed	1.43	29.81%	29.91%	40.28%

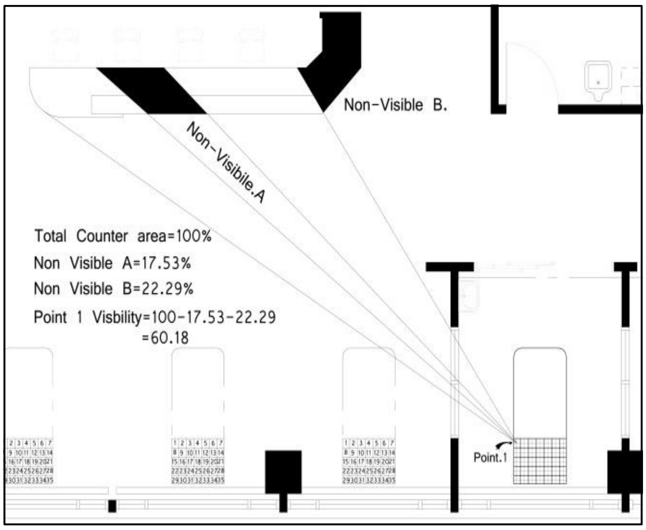
1) Patient Zone: It includes patient rooms and patient bed area with bed circulation only, the area colored as blue in the plan shows patient zone in each department.

2) Staff Zone: It includes the area used by nursing and other staff as well as services and equipment areas and support facilities like lockers and waiting rooms etc. The area colored as green in the floor plans show staff zone in each department.

3) Circulation Zone: It includes the circulation paths. lobbies and foyer etc. The yellow color in each department represents circulation zone (Table 3). Details of area distribution of the cases are shown below (Table 2).

4.3. Calculation of Patient visibility (upper third part of patient's bed)

All the patient beds were considered for visibility from the nurse station according to the criteria mentioned by Catrambone et al. (2009) Using Auto CAD and MS Excel Program. Each bed was first divided into three parts, then the upper third part of the bed was divided into 35 tiles of 150 x 150 mm size. The center of each tile was connected to the nurse station without any obstruction. The visible area of each point was calculated and the average of all points was calculated for each bed, as shown in (Figure 10).



[Figure 10] Calculation method of patient visibility

The overall visibility (Average visibility of each unit) of the ICU was calculated by taking the average of each bed visibility in the unit as shown in (Table 4).

[Table 4] Average Patient Visibility (Upper third part of patient bed)

Case No.	Number of Beds	Number of Rooms (%)	Average Patient Visibility Percentage
Case-1	15	7(31.81%)	86.56%
Case-2	7	2(22.22%)	92.97%
Case-3	16	4(20.00%)	69.76%
Case-4	4	4(50.00%)	88.13%
Case-5	19	8(29.62%)	90.43%
Case-6	10	3(23.07%)	87.65%
Case-7	16	15(48.38%)	66.13%
Case-8	12	13(52%)	74.88%

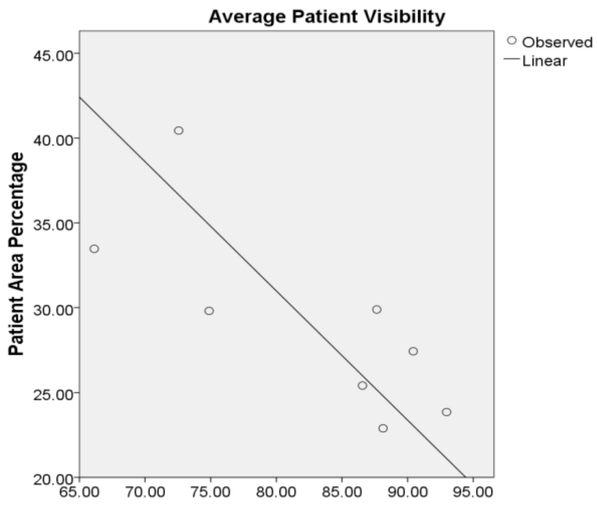
5. Synthesis

Data from the above analysis was compared with the measure of patient visibility, the measure of area distribution, and space programme were specifically tested for the correlation. The following correlations were found statistically significant.

(1) Correlation between Average Patient Visibility and Percentage of Patient Area

It was found that average patient visibility has a strong negative correlation with percentage of patient area in the unit (r^2=0.66, P=0.01. [Figure 11]. This implies that decreased percentage of patient area in the ICU may produce enhanced patient visibility and vice versa. the slope equation for the this correlation is Y=-1.449(X)+124.3,

Where Y is the total visibility of the ICU (corridor or continental type) and X is the percentage of patient area in the unit.



[Figure 11] Correlation of visibility and percentage of patient area

This equation was tested for the redesigned unit of same type, then their visibility was calculated manually and tested against the results given by the equation and it was found that the equation stands valid within a range of plus mins six.

Therefore the revised model stands valid within the given condition,

$Y= -1.449(X)+124.3\pm6.$

1. Given that the unit has a mixed programme of open bed and closed patient rooms
2. The unit have a minimum of 20% patient rooms.

For instance if the patient area (percentage) in the unit is 22% then using the above equation the visibility will range from 86.42% ~ 98.42% as shown below.

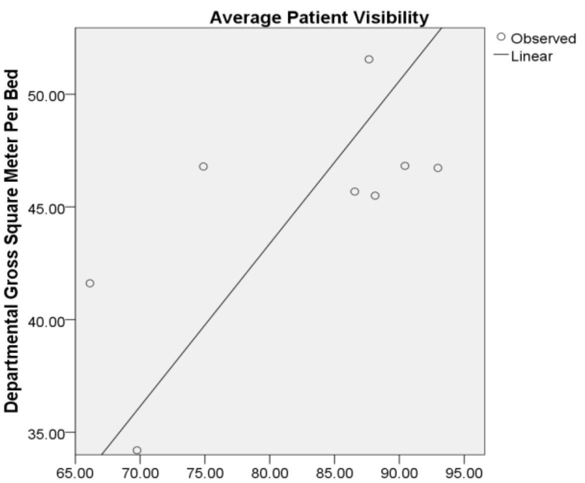
$Y=-1.449(22)+124.3\pm6$

$Y= 86.42 \sim 98.42$

To further clarify this result, the correlation of departmental gross square meter (DGSM) per bed with visibility was considered in the next step of regression analysis.

(2) Correlation between Average Patient Visibility and Departmental Gross Square Meter (DGSM) Per Bed

A moderate positive correlation ($r^2=0.473$) and $p=0.05$, was found between average patient visibility and departmental gross square meter per bed.



[Figure 12] Correlation of visibility and DGSM/bed

This implies that the above equation is not by chance, as this relation is also visible in the departmental gross square meter per bed.

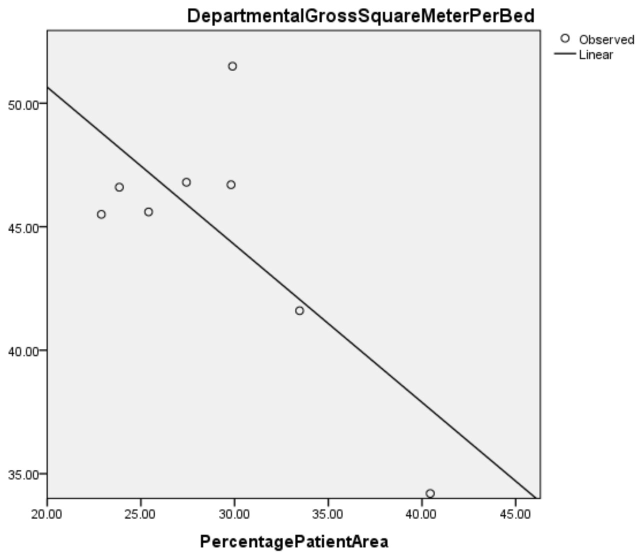
For instance consider a unit of 30 beds (26 in open bay and 4 rooms) of 1259 gross square meter. Now the DGSM per bed 41.97 and the percentage of patient area in the unit is 37.33%. now if we decrease the DGSM per bed by adding 4 beds (3 beds to the open bay and 1 bed room) the total areas will become 1348 and the DGSM per bed will become 39.65 and the percentage of patient area will become 39.68%.

Thus, it implies that by decreasing the DGSM per bed increases the percentage of patient area in the unit and decreases patient visibility in the unit.

(3) Correlation between Departmental Gross Square Meter (DGSM) Per Bed & Percentage of patient Area

A strong negative correlation ($r^2=0.535$) and $p=0.04$, was found between DGSM per bed and percentage of patient area in Korean ICU. This means that increasing the percentage of patient area will reduce DGSM per bed in Korean ICU (Figure 13).

Therefore, this correlation also support the perviouse correlations of this study.



[Figure 13] Correlation of DGSM/bed & Percentage of Patient Area

6. Conclusion

The results of this study can be concluded as:

(1) Average patient visibility and percentage of patient area in korean ICU (corridor or continental type) shows a strong negative correlation ($r^2=0.66$), $p=0.01$.

(2) Based on the above correlation, the predictive model for patient visibility in Korean ICU (corridor or continental type) can be calculated as below with the given conditions:

Y= -1.449(X)+124.3±6.

Y is the total visibility of the ICU (corridor or continental type) and X is the percentage of patient area in the unit.

Conditions:

1. Given that the unit has a mixed programme of open bed and closed patient rooms and
2. The unit have a minimum of 20% patient rooms.

The results shows that patient visibility is affected by space programme and specifically by area distribution in "corridor or continental" type ICU in Korean hospital.

The correlation of average patient visibility with percentage of patient area in above analysis was further tested with redesigned floor plan using the same floor plate, with focus on increased visibility, while keeping the staff area same and the patient area was increased/decreased and then the average patient visibility for the unit was tested with given equation. the results were within a range of plus/minus 6.

This mean that for a corridor or continental type ICU design, if the percentage of patient area if kept at 17-21% of total area, the average visibility of 94-100% can be achieved respectively.

similarly for, 21-27% patient area, the average visibility of 85-93% may achieved, and so on.

The findings of this study, although of a limited number of cases, proved that space programming and design regulations may also consider the aspect of visibility, specifically in terms of space programme and area distribution.

Future research may explore the correlation of space programme in other plan typologies.

References

Allison D, Hamilton DK. 2008."Analysis of department area in contemporary hospitals: Calculation methodologies & design factors in major patient care departments". Funded in part by the American Institute of Architects' Academy of Architecture for Health Foundation; 2008.

Bauer, H., and K. Knoblich. 1978. "[Recording of walking performance of nurses working in hospital departments]." Zeitschrift fur die gesamte Hygiene und ihre Grenzgebiete 24, no. 7 pp. 539-541.

Burgio, Louis D., et al.(1990) "A staff management system for maintaining improvements in continence with elderly nursing home residents." Journal of Applied Behavior Analysis 23, no.1 Pp: 111-118.

Cadenhead, C., and D. Anderson. (2010) "Critical care design: Trends in award winning designs." World Health Design 2, Pp: 72-77.

Cai, Hui, and Craig Zimring. 2012. "Out of Sight, Out of Reach: Correlating spatial metrics of nurse station typology with nurses' communication and co-awareness in an intensive care unit." Proceedings of the 8th International Space Syntax Symposium, Santiago, Chile. Vol. 36.

Catrambone, Cathy, et al.(2009) "The design of adult acute care units in US hospitals." Journal of Nursing Scholarship 41, no.1. Pp: 79-86.

James, W. P., & Tatton-Brown, W. (1986). Hospitals: design and development: Architectural Press.

Hendrich, Ann, Marilyn Chow, Boguslaw A. Skierczynski, and Zhenqiang Lu. 2008. "A 36-hospital time and motion study: how do medical-surgical nurses spend their time?." RCHE Publications, 50.

Hendrich, Ann, et al. (2008) "A 36-hospital time and motion study: how do medical-surgical nurses spend their time?." RCHE Publications, 50.

Kang, Chul-Hwan, et al.(2009) "The variation in risk adjusted mortality of intensive care units." Korean Journal of Anesthesiology 57.no.6. pp: 698-703.

Leaf, David E., Peter Homel, and Phillip H. Factor. 2010. "Relationship between ICU design and mortality." CHEST Journal 137, no. 5: pp. 1022-1027.

Lee, Jaemin. 2009. "The inter-hospital variations of the intensive care unit (ICU) mortality in Korea: what's the problem and what do we have to do to solve it?" Korean Journal of Anesthesiology 57, no. 6, Pp. 691-692.

Lim, Chae-Man, et al.(2015) "Critical Care In Korea: Present and Future." Journal of Korean medical science 30, no.11 Pp: 1540-1544.

Lu, Yi, et al. (2014) "Patient visibility and ICU mortality: A conceptual replication."HERD: Health Environments Research &Design Journal 7, no. 2 Pp: 92-103.

Nightingale, Florence 1863. Notes on hospitals. Longman, Green, Longman, Roberts, and Green.

Seelye, Alan.1982. "Hospital ward layout and nurse staffing*." Journal of Advanced Nursing 7, no. 3. Pp.195-201.

Society of Critical Care Medicine, 1995. Guidelines for intensive care unit design. Crit Care Med.23. pp. 582–588.

"What is Intensive Care?" http://www.ics.ac.uk/icf/patients-and-relatives/information/about-critical-care/what-is-intensive-care/,IntensiveCareSocietyUK,2016.04.14.

"The Number of Delivery Rooms, Infant Units, Operating Rooms, Emergency Rooms, Intensive Care Units (Unit: Number)" http://www.medicalkorea.or.kr/content.do?method=getContent&gcd=G1001&cmscd=CM9015,Medical Korea Statistics, 2016.04.14.

접수 : 2016년 07월 15일
1차 심사 완료 : 2016년 08월 09일
게재확정일자 : 2016년 08월 31일
3인 익명 심사 필