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An Evaluation of Pediatric Intensive Care[1]

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= Abstract =After reviewing the pediatric intensive care for the 742 patients at PICU for 11 months from February to December, 1986, we obtained the following results: The patients in thoracic surgery occupied 78.2% of all patients at PICU. The rate of admission to PICU was 86.8% in thoracic surgery and 33.9% in neurosurgery. The patients in pediatrics stayed at PICU for 11.3 days, in neurosurgery for 5.7 days and in thoracic surgery for 5.1 days. Duration of ventilatory support was 198.4 hours in pediatrics, 59.7 hours in pediatric surgery and 50.6 hours in thoracic surgery. Fatality rate reached 18.4% in pediatrics, 14.6% in pediatric surgery and 6.0% in thoracic surgery. Among patients who were below 1 year of age and who stayed longer than 8 days, fatality rate was highest. 46.4% of deaths at PICU was due to the low cardiac output syndrome. All the patients admitted to PICU had their TISS scores more than 10, which meant an increased level of critical care. TISS scores for survivors were lower than those for nonsurvivors and were decreased with time. The fatality rate of the patients with TISS scores more then 50 was 19.4%, so TISS scores could be used to assess the severity of patients indirectly. With above results, we should suggest minimal requirement of equipments for modern PICU and some guidelines for the maintenance of PICU in Korea.

Key words: ***Pediatric Intensive Care Unit (PICU), Therapeutic Intervention Scoring System (TISS), Fatality rate***

INTRODUCTION

In the second half of the 20th century, a lot of knowledge could be applied to the critically ill.

The pathophysiology of life-threatening processes such as shock, respiratory failure, and increased intracranial pressure has been explored extensively.

Advances in pharmacology and improvements in transport systems and electronic patient monitoring made the nature of critical care changed.

The evolution of the pediatric intensive care unit (PICU) has been simultaneous with the scientific and technical improvement.

At times children need special medical care, and it is appropriate, therefore, to provide them with intensive care units where care is dedicated exclusively to children by pediatric specialists.

The major objective of intensive care is to provide maximal surveillance and support of vital systems in patients with acute, but reversible, life-threatening disease. In pediatric patients, the reversal of life-threatening conditions and preservation of essential functions, especially of the brain, may make it possible for them to lead useful lives.

All critically ill children up to 15 years of age (excluding neonate) can be admitted in PICU, Children's Hospital, Seoul National University.

The purpose of this paper is to assess 11-month experiences at PICU and to make some quidelines for PICU, Children's Hospital, SNU.

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Table 1. Total number of patients, rate of admission, average length of stay, duration of ventilatory support and fatality rate in PICU, SNUH (1986)

	Total No of patient(%)	Rate of admission(%)	Average length of stay (day)	Duration of ventilatory support (hour)	Fatality rate (%)
TS	580(78.2)	82.6	5.1	50.6	35(6.0)
SP	82(11.1)	8.6	3.7	59.7	12(14.6)
NS	34(4.6)	33.9	5.7	36.0	1(2.9)
PED	38(5.1)	—	11.3	198.4	7(18.4)
Other	8(1.0)	1.0	4.4	51.6	1(12.5)

Note; TS = Thoracic surgery, SP = Pediatric surgery, NS = Neourosurgery, PED = Pediatrics Other include orthopedic surgery, plastic surgery, otolaryngology and opthalmology. The cumulative total No. of patients in PICU was 3945, average length of stay was 5.3 days and daily No. of patients in PICU was average 12.1

MATERIALS AND METHODS

This study was done on the 742 patients at multidisciplinary PICU who were admitted from February to December, 1986.

This unit admits all infants and children requiring intensive care including mechanical ventilatory support except neonates.

All patients were classified according to department, age, average length of stay, cause of death, survival, TISS scores (Cullen *et al.* 1987; Pollack *et al.* 1984 and 1985) and types of used ventilators.

The deprtments were divided into thoracic surgery, pediatric surgery, neurosurgery, pediatrics and others including orthopedic surgery, plastic surgery, otolaryngology and ophthalmology.

There was no intensive care patient in pediatric urology in 1986. The rate of admission(%) to PICU was calculated by total number of patients admitted to PICU divided by total number of patients operated at pediatric operating rooms.

So we couldn't calculate the rate of admission for pediatric department.

Length of stay at PICU for each patient was calculated by cummulative total admission days of PICU patients divided by actual total number of PICU patients.

The duration of ventilatory support was the time from the beginning of mechanical ventilation to the weaning from ventilatory support.

The fatality rate was presented according to the age, length of stay at PICU, main causes of death and TISS scores.

On the basis of survival the TISS scores were determined on admission to and on discharge from PICU, and maximum scores were evaluated.

Finally, ventilators used in PICU were classified.

RESULTS

Table 1 shows departmental distribution, rate of admission to PICU, length of stay at PICU, duration of ventilatory support and fatality rate by the department.

The patients in pediatrics (PED), thoracic surgery (TS), neurosurgery(NS), pediatric surgery (SP), were 5.1%, 78.2%, 4.6% and 11.1% of total patients respectively.

The rate of admission to PICU shown as total number of patients admitted to PICU divided by total number of patients operated at pediatric operating rooms were 86.6% in thoracic surgery, 33.9% in neurosurgery, 8.6% in pediatric surgery and 1.0% in other surgeries.

The average length of stay at PICU were 11.3 days in pediatrics, 5.7 days in neurosurgery, 5.1 days in thoracic surgery, 3.7 days in pediatric surgery and 4.4 days in other surgeries.

The durations of mechanical ventilatory support in PICU were 198.4 hours in pediatrics, 59.7 hours in pediatric surgery, 50.6 hours in thoracic surgery and 36.0 hours in neurosurgery.

The overall fatality rate was 7.6%. The fatality rates for pediatrics, pediatric surgery, thoracic surgery and neurosurgery were 18.4%, 14.6%, 6.0% and 2.9%, respectively.

The fatality rate for other suirgcal patients were 2.5%.

The average number of PICU patients per day was 12.1 in 986.

Table 2 shows distributions of the patients for

Table 2. Fatality rate related to age and average length of stay in PICU, SNUH (1986)

	Total No. of patients(%)	No. of deaths	Fatality rate(%)
Age			
under 4 wks	46(6.2)	7	15.2
1 mo — 4 yr	135(18.2)	14	10.3
1 yr — 6 yrs	366(49.3)	22	6.0
6 yrs — 10 yrs	111(15.0)	6	5.4
over 10 yrs	84(11.3)	7	8.3
Average length of stay			
1 — 2 days	416(56.1)	29	7.0
3 — 4 days	148(19.9)	5	3.4
5 — 7 days	68(9.2)	2	2.9
over 8 days	110(14.8)	20	18.0

Note: Average fatality rate in PICU SNUH was 7.6%

the age and length of stay at PICU and relationships between age, length of stay and fatality rate. 49.3% of the group was allocated to the patients between 1 year and 6 years, and 18.2% between 1 month and 1 year, 15.0% between 6 and 10 years, 11.3% over 10 years and 6.2% under 1 month.

More than half of the group (56.1%) stayed for 1 to 2 days at PICU and 19.9% of the group for 3 to 5 days, 9.2% of the group for 5 to 7 days, and 14.8% of the group over 8 days.

The fatality rates for each age groups were 15.2% under 1 month, and 1 year, 6.0% between 1 and 6 years, 5.4% between 6 and 10 years and 8.3% over 10 year.

Therefore, the highest fatality rate was in the patients under 1 month,and the next between 1 month and 1 year. The fatality rate related to length of stay at PICU was highest in the group staying over 8 days (18.0%), and 7.0% in 1 to 2 day-staying group.

The fatality rate of the patients staying for 3 to 7 days was approximately 3.0%.

Table 3 classifies main causes of death in PICU during 11-month period. The causes of death were low cardiac output (46.4%), sepsis (8.0%), hypovolemic shock (7.1%), brain damage (5.4%), acute renal failure (85.4%), myocardial infarction(3.6%) and others (6.1%).

The causes of two deaths were uncertain. Table 4 shows TISS scores by departments depending on survival, 414 PICU patients in thoracic surgery, neurosurgery, pediatric surgery and pediatrics were measured once daily, preferably in the morning and by the same observer, during stay at PICU.

Table 3. Main causes of death

Cause of Death	No of deaths(%)
Low cardiac output	26(46.4)
Myocardial infarction	2(3.6)
Sepsis	5(8.9)
Brain damage	3(5.4)
Hypovolemic shock	4(7.1)
DIC	2(3.6)
Acute renal failure	3(5.4)
Others	9(16.1)
Undetermined	2(3.6)
Total	56

Note: DIC = Disseminated Intravascular Coagulation

Survivors showed higher TISS scores on admission and lower TISS scores on discharge, which suggested that quantity of therapy could be reduced day by day.

Nonsurvivors showed higher TISS scores on discharge and lower TISS scores on admission, indicating the quantities of therapy increased progressively without any improvements.

For example, TISS scores on admission for survivors and nonsurvivors in thoracic surgery were 38.1 and 47.2, respectively, and those on discharge for survivors and nonsurvivors were 22.5 and 48.2, respectively.

Table 4. TISS Scores by departments in PICU, SNUH

	TISS on admission	TISS maximum	TISS on discharge
Survivors			
Thoracic surgery	38.1	39.2	22.5
Neurosurgery	24.5	26.8	18.0
Pediatric surgery	19.6	21.4	15.0
Pediatrics	31.2	33.9	22.5
Nonsurvivors			
Thoracic surgery	47.2	52.5	48.2
Neurosurgery	33.5	50.5	38.5
Pediatric surgery	33.0	40.5	39.8
Pediatrics	32.4	35.0	33.8

These findings were all true in Neurosurgery, pediatric surgery and pediatrics. Comparing TISS scores for survivors with those for nonsurvivors, survivors showed lower scores than those for nonsurvivors all the time, which means less therapy required for survivors. TISS scores on admission for survivors were 38.1, 31.2, 24.5, 19.6 in thoracic surgery, pediatrics, neurosurgery and pediatric surgery, respectively. But TISS score on discharge for survivors were 22.5, in thoracic surgery and pediatrics, 18.0 in neurosurgery and 1.50 in pediatric surgery.

Maximum TISS scores were in the same order with those on admission.

For nonsurvivors, TISS scores on admission were 47.2 in thoracic surgery and 32 to 34 in other departments. Maximum TISS scores for nonsurvivors were 52.5, 50.5, 40.5 and 35.0 in thoracic surgery, neurosurgery, pediatric surgery and pediatrics, respectively. TISS scores on discharge for thoracic surgery, pediatric surgery, neurosurgery and pediatrics, respectively.

Table 5 shows relationship between TISS scores and fatality rate. Among 414 patients observed for TISS scores, 91.8% survived and 8.2% did not survive. The highest fatality rate was 19.4% in the group with high TISS scores more than 50.

Table 6 shows mechanical ventilators used in PICU, SNUH in 1986. Among 742 PICU patients observed, 534 patients (72.0%) were mechanically ventilated in intubated state, 49.8% of patients were supported by Bear 2 adult volume ventilator, 25.7% by Bear Cub infant ventilator, 21.0% by Bourns infant volume ventilator and 3.5% by Engstroem Erica ventilator.

Table 5. Relationship between TISS scores and Fatality rate in PICU, SNUH

TISS scores	Lived	Died	Fatality rate
50	36	7	19.4%
40 — 49	111	8	7.2%
30 — 39	129	11	8.5%
20 — 29	63	6	9.5%
10 — 19	35	2	5.7%
0 — 9	6	0	9%
Total	380 (91.8%)	34 (8.2%)	

Table 6. Types of ventilator used for PICU patients, SNUH

Types	numbers of patients(%)
Bear 2	266(49.8)
Bear Cub	137(25.7)
Bourns	112(21.0)
Engstrom Erica	19(3.5)
Total	534

Note: Among 742 PICU patients, 534 patients (72.0%) were mechanically ventilated

DISCUSSION

One of the most important contributions to medicine during the past decade has been the application of new knowledge in biology and technology to the resuscitation and intensive therapy of critically

ill and injured patients (Safar and Grenvik 1971).

Critical care medicine encompasses emergency care for life-threatening conditions and intensive care. Resuscitation is part of both. Emergency care includes life-support at the scene, during transportation and in the hospital receiving units.

An intensive care unit (ICU) is a specific area of the hospital where sophisticated monitoring, titrated life-support and definitive therapy for potentially salvable patients with acutely life-threatening illness or injury can best be provided. The unit's staff, composed of physicians, nurses, technicians and ancillary personnel, must be trained and exerience to provide surveillance and support of single or multiple organ failure. It is impossible to equip and staff every hospital bed for modern life-support. Therefore, the concentration in ICUs of potentially salvable critically ill and injured patients has become widely accepted. Such concentration offers the following advantages; (1) physicians especially trained in resuscitation and support of vital organ function can give more continuous attention to these patients; (2) a small select group of nurses trained in special methods can serve more patients; (3) resuscitation and monitoring equipment can be concentrated in one area; (4) the hospital does not have to duplicate and maintain special equipment and personnel at various places.

Most present intensive care units have evolved via post-anesthetic recovery rooms (PAR) in which patients remain until they have recovered from anesthesia; and post-surgical recovery rooms, also called surgical ICUs, which are staffed around the clock to provide care for surgical patients as long as they are critically ill. In Korea, Kim *et al.* (1976) made the first report on respiratory intensive care in Seoul National University, when they used only pressure limited ventilator (Bird Mark 7) for postoperative and critical ill patient, and when residents in the department of anesthesiology analyzed blood gases in ICU by themselves. From then on, anesthesiology analyzed blood gases in ICU by themselves. From then on, anesthesiologists who were responsible for respiratory care and resuscitation of all ICU patients and who worked as obligatory team members were available in the ICU around the clock.

The elements of intensive care (Downes and Raphaely (1979) have been defined as; (1) geographic full-time physician specialists in anesth esiology, medicine (pediatrics), general surgery and its subspecialties; (2) a full-time physician director of intensive care; (3) nursing and allied health personnel specially trained in care on the critically ill; (4) availability of resuscitation and respiratory therapy equipment and drugs; (5) monitoring and alarm systems for continuous assessment of vital functions; (6) a 24-hour laboratory survices for the rapid determination of pH and blood gas tensions, oxygen content, hemoglobin, blood sugar and plasma sodium, potassium, calcium, osmolarity and total protein; (7) a 24-hour radiology service responsive to the needs of the critically ill; (8) location of these facilities in one area of the hospital. Pediatric intensive care involves these elements as they apply to critically ill patients ranging from the newborn to the late adolescent.

This requires that the personnel involved be thoroughly familiar with pediatric anatomy, physiology, pharmacology, pathology, psyschology and appropriate technical maneuvers.

As previously mentioned, one of the purposes of this paper is to provide guidelines for PICU which will serve as a reference for those wishing to develop new units or to modify existing ones in Korea. The contributors to this set of guidelines may include anesthesiologists, pediatricians, surgeons, engineers, technicians, nurses, and child life specialists who focus on the care of the children in hospitals.

Table 1 shows that rate of admission of patients was 86.6% in TS and 33.9% in NS. The patients in pediatrics stayed (11.3 days) and needed duration of ventilatory support longer than other patients. This indicated that PICU was utilized mainly to recover the postsurgical patients.

In this report, mortality was highest (15.2%) in the patients under 4 weeks and in the patients staying more than 8 days in PICU.

Generally the patients who stayed long time at PICU had many postoperative complications, so mortality might be high.

Table 3 revealed main causes of death. The low cardiac output ranked highest (46.4%) as the main cause of death. This hinted us that in PICU cardiac output monitoring is important. To monitor cardiac output Swan-Ganz catheterization can be done frequently. Measurements of transcutaneous oxygen tension and urine output and determination of mixed venous oxygen saturation may help to assume cardiac output indirectly.

The therapeutic intervention scoring system (TISS) is a widely accepted method for classifying critical care patients (Keene and Cullen 1983). It has been utilized in the United States and abroad for many purposes which include; (1) determining

Table 7. Trends of ICU patients who received open heart surgery at the Department of thoracic surgery in Seoul National University

	1975 — 1976.3	1976.4 — 1978	1979	1980*	1982*	1986*
Population(%) vs total patients	41.0	69.2	69.0	62.3	73.5	78.2
Fatality rate in ICU(%)	—	11.0	11.2	7.6	4.7	6.0
Ventilatory support (day)	2.3	1.3	0.7	1.2	1.2	2.1
Average length of stay in ICU (day)	4.2	—	—	2.4	1.6	5.1
Types of ventilator						
Pressure type (%)	100.0	—	44.2	37.1	30.3	25.7
Volume type (%)	0	—	52.2	62.9	68.7	74.3
Authors	Kim *et al.* 1976	Kim *et al.* 1979	Kim *et al.* 1981	Kim *et al.* 1982	Kim *et al.* 1983	this report

The data before 1986 are from respiratory ICU patients and data in 1986 from PICU patients.
*; includes general thoracic patients in addition to cardiac patients.

severity of illness; (2) establishing nurse: patient ratios in the ICU; (3) assessing current utilization of hospital's intensive care beds; (4) establishing future needs and numbers of ICU beds. The system is simple to apply and the data are easily reduced.

An experienced observer (e.g., ICU nurse) can assign interventions and tally up points in a matter. ICUs have traditionally provided observation, monitoring, and therapeutic intervention. Patients who need observation with slight intervention most likely need not reside in an ICU. Rothstein and Johnson (1982) reported that patients whose TISS points were less than 10 had a short stay in the ICU and ideally could be taken care of in an intermediate care setting that did not require the concentration of personnel and equipment that the ICU provided. For this reason, they defined patients requiring an increased level of care as those with TISS score more than 10.

In our study, TISS points on admission, maximum and discharge were highest in thoracic surgery for both survivors and nonsurvivors, which means that they require more intensive and concentrating care than the patient in any other department. Interesting trend was for nonsurvivors to have an increasing score with time while survivors tended to maintain or decrease their scores. All the patients had TISS points more than 10, so they all required intensive care in this study. Mortality in critically ill children was high in the patients whose TISS points was more than 50 in this study.

Comparison of data between units using TISS points is possible, but there are limitations to its use. Any comparison would presume that a patient with the same illness would be treated in the same way in different units. Given the marked differences in patient's age and illness in different units, comparison of TISS scores between units would also imply that patients with similar TISS scores were equally ill. If one were to design a program to reduce mortality in PICU population, one must take into account certain facts. Reduction in mortality in children with congenital anomalies can best be accomplished by improved prenatal assessment, prevention and the development of new surgical techniques. Pollack *et al.* (1984) evaluated 294 PICU patients and reproted that severity of illness measured by physiologic stability index (PSI) (Yeh *et al.* 1984; Ruttimann *et al.* 1986) divided by quantity of care measured by TISS was highest in medical patients and lowest in cardiovascular surgery patients.

In Table 6 volume type ventilator (79%) was used more often than pressure type ventilator (21%). This corresponded to the fact that recently even for pediatric ventilatory care volume type ventilator prevails over pressure type one.

The PICU is considered to be a hospital unit which provides treatment to children with a wide variety of illnesses of a life-threatening nature, including children with highly unstable conditions and those requiring sophisticated medical and surgical intervention. For example, this type of unit would be able to provide care for severe multiple trauma and open heart surgery patients.

Table 7 shows the trends of ICU patients, espe-

Table 8. The equipments necessary in PICU

1. Portable equipment
   - Emergency cart
   - Spot light
   - IV fluid warmer
   - Suction machine
   - Otoscope/Ophthalmoscope
   - Cribs
   - Incubators
   - Heating/Cooling blankets
   - Air-Oxygen blenders
   - Pacemaker
   - Transcutaneous PO_2/PCO_2
   - End-tidal PCO_2 monitor
   - Respirators
   - Doppler ultrasound BP device
   - Defibrillator and cardioverter
   - Electronic thermometer
   - Rocking chair*
   - Beds
   - Oxygen tanks
   - Humidifiers
   - Oxygen analyzers
   - EEG
   - Portable transport monitor
   - Infusion pump including microinfusion capability
   - Automated blood pressure apparatus
   - Resuscitation bag-valve-mask device
   - Servo controlled heating units with or without open crib
2. Small equipment
   - Emergency drug
   - Artificial airways
   - Equipment for vascular access
   - Tracheal intubation equipment
   - Isolation equipment
3. Monitoring equipment for continuous monitoring of;
   - ECG and heart rate
   - Temperature
   - Central venous pressure
   - Intracranial pressure
   - Respiration
   - Arterial pressure
   - Pulmonary arterial pressure
   - Arrhythmia alarm
   - 3-5 simultaneous pressure capability

*; not equipped in Children's Hospital, SNU.

cially who received open heart surgery in Seoul National University Hospital.

The patient population who received open heart surgery and/ or chest surgery is increasing year by year, probably due to increased GNP and acceptance of medical insurance system in Korea.

The pressure limited ventilator are changing into volume-limited ventilator. Fatality rate showed decreasing tendency, but it was increased in 1986, which is due to increased number of extremely young-aged patients and much complicated congenital heart diseases.

Table 8 shows the important equipments which are necessary in the tertiary PICU (committee on hospital care and the pediatric section of the society of critical care medicine 1983).

The above mentioned items should be interpreted as quidelines only. Because of ongoing development in this field, periodic revisions of PICU guidelines will be necessary. But all the equipments are not necessarily complete. Extensive physiologic monitoring is one of the hallmarks of the PICU. Basic monitoring capability should provide for ready determintion of blood pressure (by sphygmomanometer, Doppler ultrasound, flush technique, oscillometry, or intra-arterial cannulation), temperature, heart rate and corresponding waveform. Central venous, pulmonary arterial, intrcacranial, and esophageal pressure monitoring with display of corresponding waveforms should be available. An equipment for simultaneous measurement of three or more pressures is necessary. All pressure, heart rate, and respiration monitors should have high-low visible and audible alarms. Availability of hard copy of all waveforms is helpful. Appropriate electrical safety provisions should be assured to protect the patient. It may be advantageous between other units of the hospital. Availability of biomedical engineering resources to the PICU is becoming extremely important.

Parents should be allowed to stay with the critically ill chiuld as much as possible. The familiar face and voice of a parent may reach a child who appears comatose but is beginning to respond to stimuli. For both parents and staff it is very important to keep the atmosphere positive, pleasant, and as much the feeling from hopelessness as possible.

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＝국문초록＝

소아 중환자 관리의 고찰

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1982년 2월부터 12월까지 11개월에 걸쳐 서울대학교 병원 소아중환자실에서 집중치료를 받은 742명의 소아환자를 고찰한후 다음과 같은 결론을 얻었다.

과별분포를 보면 흉부외과가 78.2%로 가장 많았고, 중환자실 이용율은 흉부외과가 86.6%, 신경외과가 33.9%이었으며, 중환자실 체류일자는 소아과가 가장 길어 11.3일, 신경외과 5.7일, 흉부외과 5.1일 순서이었다. 인공 호흡기 사용 시간은 소아과 환자가 198.4시간, 소아외과 59.7시간, 흉부외과가 50.6시간이었다. 사망율은 소아과 18.4%, 소아외과 14.6%, 흉부외과 6.0%의 순이었으며, 1세미만의 환자 및 8일 이상 체류환자의 사망률이 높음을 보여주었다. 사망원인은 저심박출량이 46.4%로 현저히 많았다. 치료의 양적 판정을 하는 TISS 점수는 흉부외과가 타과 보다 높으며, 생존자는 시간 경과에 따라 점수가 감소하고, 사망자는 점수가 변하지 않거나 증가하는 양상을 보여 주었다. TISS 점수가 50점이상자의 사망례가 특히 많았으며 이는 뚜렷한 상관관계를 지을수는 없을지라도 TISS 점수가 간접적이나마 질환의 중증 판정에 도움이 되리라 결론지을수 있겠다.

상기 고찰과 더불어 한국실정에 맞는 중환자실에 필요한 장비를 열거하였으며 중환자관리실 운영의 지침을 다소나마 제시하고자 하였다.