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Complications during Ventilatory Support in Patients with Acute Respiratory Failure

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When ventilatory support becomes necessary in patients with acute respiratory failure, there is an associated increase in complications.

We reviewed the charts of acute respiratory failure patients with the ventilatory support retrospectively who were admitted to the General Intensive Care Unit, Yonsei University College of Medicine, Seoul, Korea for the 6 months period, from March through August, 1990. The data included incidence of complications, morbidity and mortality, and reasons for and the duration of the ventilatory support. Of 269 patients receiving the ventilatory support, 107 patients (39.8%) developed 159 complications including alveolar hyperventilation (56 times), premature extubation (20 times) and right bronchial intubation (16 times). A single complication was associated with mortality rate of 19.5%, while with two or more complications, mortality rate was 60%, giving an average mortality rate of 29% when the complications were identified. The highest incidence of complications was in patients with multiple organ failure (80%). The highest mortality rate (50%) occurred in patients with heart failure. Patients with the ventilatory support less than one day had 23% incidence of complications and 27% mortality, while those with support for more than one month, these figures were 90.0% and 40.0% respectively ($p<0.05$). In patients with complications, the vital capacity and the negative inspiratory force were 13.30 ± 0.83 ml/kg, and -20.58 ± 1.60 cmH_2O, and NIF was lower than that of uncomplicated patients ($p<0.05$). In patients with complications, the ventilatory support was used for 15.16 ± 5.52 days, and the days spent in ICU was 25.86 ± 8.96 days, compared with 2.87 ± 0.33 and 6.76 ± 0.44 days in those without complications ($p<0.05$). Our study showed that the mortality rate was higher in the patients with higher complication incidence, but further study has to be done to evaluate the association of complications with mortality or the cause of death in patients with complication during the ventilatory support.

Key Words: Complications, ventilatory support, intensive care unit, retrospective study, monitoring

When ventilatory support becomes necessary in patients with acute respiratory failure, there is an associated increase in complications (Zwillich *et al.* 1974, Strieter *et al.* 1990). These complications include injury during intubation, right main stem bronchial intubation, endotracheal tube malfunction, alveolar hypoventilation, pneumothorax, atelectasis, pulmonary infection, disconnection of the ventilator and technical apparatus failure etc. Awareness of the variety of possible problems and careful attention and monitoring are needed to minimize morbidity and mortality during ventilatory support. We have retrospectively assessed the incidence of several complications in a six months period in a University Intensive Care Unit, and the association with mor-

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bidity and mortality.

PATIENTS AND METHODS

We reviewed the charts of the patients who were intubated and ventilated between March 1st, 1990 and August 31st, 1990 under the supervision of faculty and residents of the Department of Anesthesiology who were in charge of the Intensive Care Unit of Yonsei Medical Center. Ventilators used during this period include Bennett MA-II, 7200 (Puritan Bennett Corporation, Santa Monica, CA, USA) for adults, and for infants, either Bourns LS 104-150 (Bourns Life System Division, Riverside, CA, USA) or Siemens Servo 900C (Siemens-Elema AB, Ventilator Division, Solina, Sweden). No institutional Review Board Approval is available, and no patients are identified in the report.

The complications identified during ventilatory support are listed in Table 1.

The diagnosis of right bronchial intubation required roentgenographic evidence that the distal tip of the endotracheal tube was located on the right side of the bronchial tree, with definite physical signs of unilateral ventilation which resolved when the tube was withdrawn above the bifurcation. Premature extubation was defined as removal of the endotracheal tube by a physician in cases which required reintubation because of the respiratory failure within 24 hours. Self extubation designated removal of the tube by the patient.

Complications attributable to operation of the ventilator were: 1) mechanical failure, defined as failure of the ventilator to cycle or to give effective pressure or tidal volume; 2) alarm failure consisting of failure of the ventilator alarm system to sound when its sensor was disconnected from the ventilator.

Alveolar hypoventilation during assisted ventilation was defined as the occurrence of acute respiratory acidosis such as $pH<7.30$ and $PaCO_2>50$ mmHg. Alveolar hyperventilation was defined as respiratory alkalosis with $pH>7.50$ and $PaCO_2<30$ mmHg. Pneumothorax was defined by detection of mediastinal shift on a chest roentgenogram or the release of air under pressure upon the insertion of the thoracotomy tube. Pneumonia was defined as an appearance of new infiltration visible on the chest roentgenogram for 24 hours or more after the initiation of ventilatory support associated with elevation of temperature, leukocytosis and evidence of growth of a bacterial pathogen on culture. Hypotension was defined as a drop in systolic blood pressure of 20 mmHg or more when the mechanical ventilation had begun.

The patients were classified into five categories according to the cause of ventilatory support: 1) acute respiratory failure developed as a result of trauma; 2) acute respiratory failure following surgery; 3) acute respiratory failure in patients with primary lung disorders; 4) acute respiratory failure in patients with cardiac disease; 5) acute respiratory failure in patients with multiple organ failure. 107 patients with complications are Group 1, and 162 without complications are Group 2.

The Chi-squared analysis was used to test the significance of differences between groups of the incidence of complications and the mortality rate according to the frequency of complications, the primary reason for and the duration of the ventilatory support. The t-test was used to compare the variables such as the ventilator settings, the vital signs, the arterial blood gas data during the ventilatory support, spontaneous lung volume as vital capacity and inspiratory force measured during weaning period, the duration of ventilatory support and ICU stay between the two groups. P value less than 0.05 was considered as statistically significant.

RESULTS

Complications occurred 159 times in 107 patients, an incidence of 39.8%. The most common complication was alveolar hyperventilation (56 times), and premature extubation (20 times) was the second. The incidence of all complications is given in Table 1. There was no significant difference of age and weight between two groups (Table 2). Table 3 contains the frequencies of complications and

Table 1. Complications and their frequencies

Complications	Frequencies
Attributable to intubation, extubation and tube malfunction	60
Right mainstem bronchial intubation	16
Premature extubation	20
Self extubation	11
Tube malfunction	1
Hoarseness	8
Aspiration	4
Attributable to operation of ventilator	13
Machine failure	9
Alarm failure	4
Medical complications	86
Alveolar hypoventilation	7
Alveolar hyperventilation	56
Pneumothorax	9
Atelectasis	2
Pneumonia	10
Hypotension	2
Total	159

Table 2. Age and weight distribution

mean±SE

	No.	Age(year)	Weight(kg)
Group 1	107	34.89±2.47	42.50±2.38
Group 2	162	31.96±1.86	43.98±1.83

No.: number of patients: Group 1 is the patients with complications and Group 2 is the patients without complications

mortality. There were no deaths in group 2. Seventy seven percents of the group 1 had only one complication and in this subset, the mortality rate was 19.5 %, whereas with two or more complications, the mortality rate was 60%. Overall, the mortality rate of the group 1 was 29%. The relationships between the complication rates and the indication for the ventilatory support is presented in Table 4. 213 postoperative patients experienced the lowest complication rate of 31.5% while those with multiple organ failure had the highest rate, 80%. The highest mortality rate occurred among patients with cardiac failure (50%).

Table 5 shows that both complications rate and mortality were increased in proportion to the duration of ventilatory support. There was no significant difference of ventilator parameters between groups (Table 6). Table 7 illustrates the differences of blood gas values, blood pressure and heart rates between groups, none of which seemed to be considered as clinically significant. Group 1 had significantly lower average of negative inspiratory force (Table 8) and far longer ventilatory support (Table 9).

DISCUSSION

The reported incidence of complications and mortality associated with the ventilatory support is surprisingly high (Zwillich *et al.* 1974; Strieter and Lynch. 1988; Gillespie *et al.* 1990), and comparable to or higher than found in

Table 3. Frequencies and incidence of complications and morality(percent)

Frequency of Complication	No. of patients	Incidence of complication	No. of deaths	Mortality(%)
Group 1				
Once	82	76.6	16	19.5
More than twice	25	23.4	15	60.0
Group 2				
None	162	0	0	0
Total	269	39.8	31	11.5

Group 1 is the patients with complications and Group 2 is the patients without complications.

Table 4. Incidence of complications and outcome according to primary reason for vent ilatory support

Primary reason	No.of Ventilatory Patient	Complications		Deaths	
		No. of pt.	incidence(%)	No. of pt.	Mx.(%)
Trauma patient	9	5	55.6	0	0
Cerebral contusion	1	0			
Chest trauma	8	5			
Postoperative patient	213	67	31.5	12	5.6
Cardiac operation	175	56			
Abdomen operation	25	8			
Lung operation	11	2			
Other operation	2	1			
Primary lung disorders	28	20	71.4	11	40.7
Pneumonia	13	8			
ARDS	9	8			
COPD	5	3			
Asthma	1	1			
Heart failure	4	3	75.0	2	50.0
Multi-Organ Failure	15	12	80.0	6	40.0
Total	269	107	39.8	31	11.5

No., number; Mx, Mortality rate; ARDS, adult respiratory distress syndrome; COPD, chronic obstructive pulmonary disease; CHF, congestive geart failure; MI, myocardial infarction.

Table 5. Duration with ventilatory support and incidence of complication and outcome

Vent. day	No.	Complication		Deaths	
		No.	Incidence(%)	No.	Mortality(%)
<1	72	17	23.0	1	2.7
2- 7	157	60	38.2	16	10.2
8-14	18	12	66.7	5	27.8
15-30	12	9	75.0	4	33.3
30<	10	9	90.0	4	40.0
Total	269	107	39.8	31	11.5

No., number of patients
Vent. Days, Duration with ventilatory support.

this study. Whereas Gillespie *et al.* (1990) reported the mortality rate of 25% in both surgical and non-surgical patients, we found only 11.5% mortality in overall patients. Although the prognosis of patients with respiratory failure, treated with assisted or controlled ventilation, has improved since the advent of the respiratory intensive care unit, the number of recognized complications has increased as experience with mechanical ventilation increased (Zwillich *et al.* 1974). The outcome may depend on the failure of other organ systems than of the lung (Gillespie *et al.* 1990; Fleming *et al.* 1972).

Inadequate airway management has been a major complicating factor (Mathew *et al.* 1990). Although in this study there were 16 right bronchial intubations, they were diagnosed promptly, and there were no associated deaths. The incidence of the airway complications may have increased in proportion to the number of intubations in patients. The incidence of pulmonary barotrauma has been reported as 10~39%, varying with diagnosis (Mathru *et al.* 1983; Cullen and Caldera. 1979), higher than observed in this study (5%). This lower incidence may reflect our low proportion of patients with adult respiratory distress syndrome or chronic obstructive pulmonary disease. Factors implicated as causing barotrauma include high levels of PEEP or CPAP,

Table 6. Ventilatory settings (mean±SEM)

Initial Period	FiO_2	V_T	RR	PIP
Group 1	0.66±0.02	11.38±0.23	17.02±0.76	22.71±0.96
Group 2	0.56±0.01	11.06±0.15	16.18±0.59	22.34±0.37
Maintenance Period	FiO_2	V_T	RR	PIP
Group 1	0.45±0.02[a]	11.05±0.23	16.63±0.87	24.48±1.01
Group 2	0.42±0.01[a]	11.00±0.18	16.27±0.55	23.80±0.84

Group 1 is the patients with complications and Group 2 is the patients without complications. Duration with ventilatory support was divided into two periods as initial, maintenace period. Initial period is defined as immediately after admission to ICU and maintenance period as one day after admission to ICU. FiO_2, Fraction of inspired oxygen, % /100; V_T tidal volume, ml/kg; RR, setting rate of ventilator, frequency/minute; PIP, peak inspiratory pressure, cmH_2O.

[a] $P<0.05$, between Group 1 and Group 2.

Table 7. Vital signs and arterial blood gases during initial and maintenance period of ventilatory support and pre-extubation period(mean±SEM)

Initial Periods	MAP	PR	PH	PO_2	PCO_2
Group 1	84.75±1.92[a]	117.93±2.86	7.42±0.01	145.20±8.69[a]	37.68±0.97
Group 2	89.43±1.33[a]	117.00±2.30	7.43±0.01	189.89±7.48[a]	38.06±0.51
Maintenance Period	MAP	PR	PH	PO_2	PCO_2
Group 1	86.16±2.01	108.45±2.77	7.48±0.01	113.61±4.26[a]	34.67±0.68[a]
Group 2	91.34±1.10	105.96±2.19	7.44±0.02	126.66±3.52[a]	36.87±0.41[a]
Pre-extubation Period	MAP	PR	PH	PO_2	PCO_2
Group 1	88.47±2.26	110.81±3.35	7.30±0.22	133.50±7.09	39.57±0.89
Group 2	89.94±1.25	104.00±2.00	7.43±0.00	131.24±4.70	40.25±0.53

[a] $P<0.05$ between Group 1 and Group 2. Group 1 is the patients with complications and Group 2 is the patients without complications. The duration of ventilatory support is divided into 3 periods as initial, maintenance and pre-extubation periods. MAP, mean arterial pressure, mmHg; PR, pulse rate, frequency/minute; PO_2 mmHg; PCO_2 mmHg.

Table 8. Vital capacity(VC) and inspiratory force (IF) before extubation(mean±SEM)

	VC(ml/kg)	IF(-cmH20)
Group 1	13.30±0.83	20.58±1.60[a]
Group 2	14.48±1.14	27.05±2.51[a]

[a] $P<0.05$ between Group 1 and Group 2. Group 1 is the patients with complications and Group 2 is the patients without complications.

Table 9. Duration with ventilatory support and ICU stay(mean±SEM)

	Vent. Day	ICU Day
Group 1	15.16±5.52[a]	25.86±8.96
Group 2	2.87±0.33[a]	6.76±0.44

Vent. Day, Ventilatory day.

[a] $P<0.05$ between Group 1 and Group 2. Group 1 is the patients with complications and Group 2 is the patients without complications.

large mechanical or manually delivered tidal volumes, high peak inspiratory pressure, and high ventilatory frequency (Parker *et al.* 1984; Haake et al. 1987; Adkins *et al.* 1991). The peak inspiratory pressure in our group was conservative as seen in table 6. It has been recommended that, when high PEEP is needed, pulmonary arterial and wedge pressure should be monitored directly (Fretscher *et al.* 1991; Santora *et al.* 1991; Collee *et al.* 1987).

Adkins *et al.* (1991) demonstrated a higher incidence of barotrauma in young rabbits, and attributed this result to the more compliant lung-chest wall system. No age or weight influence was seen in our study groups as in other's (Pesau *et al.* 1992).

A longer period of hospital stay before Intensive Care Unit admission and presence of chronic obstructive pulmonary disease were significant characteristic of patients with pneumonia when compared with the patients without nosocomial pulmonary infection(Jimenez *et al.* 1989). The important pathogenic mechanism of nosocomial pneumonia is the oropharyngeal colonization by gram negative bacilli which are usually present in intubated patients. Jimenez *et al.* (1989) and Johanson *et al.* (1988) using highly specific methods of diagnosing pneumonia such as a protected brush catheter, transthoracic needle aspiration of pleural fluid and blood culture, showed a 23% incidence of pneumonia in patients with ventilatory support. The lower incidence in our study may reflect the higher fraction of postoperative patients, shorter duration of ventilation and of ICU stay.

Although alveolar hyperventilation was the most common complication in this study, there were no significant differences of ventilator settings and blood pressure between group 1 and 2 (Table 6, 7), and the parameters were appropriate (Task force, SCCM, 1991). Pneumonia reportedly increases the duration of mechanical ventilation from about 10 to 32 days. In general, we found longer duration of ventilatory support and longer ICU stay when complications occurred.

For example, with 2~7 days of the ventilation, the complication and the mortality rates were 38.2 % and 10.2% respectively while with more than 30 days, the incidence and mortality were 90% and 40% respectively, values higher than those in the report of Jimenez *et al.* (1989).

To avoid the potentially lethal pulmonary complications resulting from water retention in ventilated patients, careful monitoring of intake and output is essential (Sladen *et al.* 1968; Cohen *et al.* 1991). Bronchoscopy in our atelectatic patients improved their oxygenation and facilitated reexpansion (Koh *et al.* 1990). Because of the fulminant nature of ARDS, and the frequent association with other injury, it has higher mortality rate than pulmonary edema due to cardiac failure (Peppe *et al.* 1982; Fowler *et al.* 1983). The incidence of the complications and the mortality rates of our patients with lung pathology (pneumonia, ARDS, COPD and asthma) were higher than those of any other conditions. Sepsis was a major predisposing factor for complication of acute lung injury. Patients with multiple organ failure experienced the highest incidence of complications in our group (80%) as in Gillespie's (81%) (Gillespie *et al.* 1990).

In our study, the mortality rate was higher in patients with higher complication rate needing ventilatory support. But we could not evaluate that the high mortality rate might be due to a high complication incidence. Further study has to be done to assess the exact cause of mortality in the patients with complications during the ventilatory support.

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REFERENCES

Adkins WK, Hernandez LA, Coker PJ, Buchanan

B, Parker JC: Age affects susceptibility to pulmonary barotrauma in rabbits. *Crit Care Med 11: 390-393, 1991*

Cohen IL, Bari N, Strossberg MS, Weinberg PF, Wackman RM, Millistein BH, Fein IA: Reduction of duration and cost of mechanical ventilation in an intensive care unit by use of a ventilatory management team. *Crit Care Med 19: 1278-1284, 1991*

Collee GG, Lynch KE, Hill RD, Phill D, Zapol WM: Bed side measurement of pulmonary capillary pressure in patient with acute respiratory failure. *Anesthesiology 66: 614-620, 1987*

Cullen DJ, Caldera DL: The incidence of ventilator induced pulmonary barotrauma in critically ill patients. *Anesthesiology 50: 185-190, 1979*

Fleming WH, Bowen JC, Hatcher CR: Early complications of long term respiratory support. *J Thorac Cardiovasc Surg 64: 732-738, 1972*

Fowler AA, Hamman RF, Good JF, Benson KN, Baird M, Eberle DJ, Petty TL, Hyers TM: Adult respiratory distress syndrome: Risk with common predispositions. *Ann Intern Med 98: 593-597, 1983*

Fretscher R, Kloss T, Guggenberger H, Heuser D, Schmid HJ: Pulmonary artery occlusion-left atrial pressure gradient: An important factor in determining pulmonary venous vascular resistance in acute pulmonary failure. *Crit Care Med 19: 399-404, 1991*

Gillespie DJ, Marsh HM, Divertie MB, Meadows: Clinical outcome of respiratory failure in patients requiring prolonged mechanical ventilation. *Chest 90: 364-369, 1990*

Haake R, Schlichtig R, Ulstad DR, Henschen RR: Barotrauma pathophysiology, risk factors and prevention. *Chest 91: 608-613, 1987*

Jimenez P, Torries A, Rodriguez-Roisin, Bellacasa PJ, Aznar R, Gatell JM, Agusti-Vidal A: Incidence and etiology of pneumonia acquired during mechanical ventilation. *Crit Care Med 17: 882-885, 1989*

Johansen WG, Seidenfeld JJ, Gomerz P, Santos RDL, Coalson JJ: Bacterial diagnosis of nosocomial pneumonia following prolonged mechanical ventilation. *Am Rev Respir Dis 132: 259-264, 1988*

Koh SO, Kim JH, Oh HK: Clinical experiences of fiberoptic bronchoscopy in patients with respiratory failure in the Intensive Care Unit. *Yonsei Medical J 31: 219-224, 1990*

Mathew JP, Rosenbaum SH, O'Connor T, Barash PG: Emergency tracheal intubation in the intensive care unit: Physician error or patient disease? *Anesth Analg 71: 691-696, 1990*

Mathru M, Rao TLK, Venus B: Ventilator induced barotrauma in controlled mechanical ventilation versus intermittent mandatory ventilation. *Crit Care Med 11: 359-361, 1983*

Parker JC, Townsley MI, Rippe B, Taylor AE, Thigpen J: Increased microvascular permeability in dogs lungs due to high peak airway pressures. *J Appl Physiol (Respirat) 57(6): 1809-1816, 1984*

Peppe PE, Potkin RT, Reus OH, Hudson LD, Carrico CJ: Clinical predictors of the adult respiratory distress syndrome. *Am J Surg 144: 124-130, 1982*

Pesau B, Falger S, Berger E, Weimann J, Schuster E, Leithner C, Frass M: Influence of age on outcome of mechanically ventilated patients in an intensive care unit. *Crit Care Med 20: 489-491, 1992*

Santora T, Ganz W, Gold J, Wittman M, Leyerle B, Swan HJC, Shabot MM: New method for monitoring pulmonary artery catheter location. *Crit Care Med 19:422-426, 1991*

Sladen A, Layer MB, Pontoppidan H: Pulmonary complications and water retention in prolonged mechanical ventilation. *New Engl J Med 279: 448-453, 1968*

Strieter RM, Lynch 111 JP: Complications in the ventilated patient. *Clin Chest Med 9: 127-139, 1988*

Task force on guidelines; society of critical care medicine: Guidelines for standards of care for patients with acute respiratory failure on mechanical ventilatory support. *Crit Care Med 19: 275-278, 1991*

Zwillich CW, Pierson DJ, Creagh CE, Sutton FD, Schatz E, Petty TL: Complications of assisted ventilation, A prospective study of 354 consecutive episodes. *Am J Med 57: 161-170, 1974*