Effect of Closed Versus Open Suction System on the Occurrence of Ventilator Associated Pneumonia in Neonates

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Abstract: Clearance of secretions is mandatory in mechanically ventilated neonates, because accumulation of secretions may lead to airway occlusion and serious physiological abnormalities. Although treacheal suctioning is a necessary intervention in the care of intubated neonates, it is not a benign one. It is associated with various complications such as hypoxemia, atelectasis and ventilator associated pneumonia. This study aimed to determine the effect of closed versus open suction system on the occurrence of ventilator associated pneumonia in neonates. The study was conducted at the Neonatal Intensive Care Unit of El- Shatby Maternity University Hospital in Alexandria. A convenient sample of 50 mechanically ventilated neonates were selected. They were chosen within the first 24 hours from initiation of ventilatory support. The neonates were randomly assigned into two groups. Twenty five neonates were suctioned by closed suction system, and the other 25 neonates were suctioned by open suction system. Neonates of both groups were chosen alternatively. The results revealed that neonates of the open suction group experienced ventilator associated pneumonia more than those of the closed suction group. Moreover, the growth of the isolated organisms from Non Bronchoscopic Bronchoalveor Lavage cultures among neonates of the closed suction group was less than among those of the open suction group.
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1. Introduction

Recently, many advances regarding the care of the critically ill neonates have been established. Sophisticated technology exciting now in NICU allows those neonates to overcome many crises. In such units advanced technology together with trained healthcare professionals are available to provide specialized care for admitted neonates. This kind of care enables helpless neonates particularly those on mechanical ventilation (MV) to have greater chance for surviving as well as better health. [1-3]

Mechanical ventilation entails the use of sophisticated life support technology aimed to maintain tissue oxygenation and removal of carbon dioxide. Mechanical ventilators are devices that can create a flow of gas into and out of the lungs by manipulation of airways pressures. MV is associated with numerous complications and hazards which can be life threatening. The decision to initiate mechanical ventilatory support is a serious one that requires sound clinical judgment and clear understanding of its indications.[4-8]

The implementation of MV implies several changes in the neonate's airways. The loss of the airway sterility by colonization of bacteria within a few hours of starting MV is considered the most important change when neonates are intubated. Many complications can occur in these circumstances. Ventilator associated Pneumonia (VAP) is the most important infectious complication in neonates undergoing MV. Certainly, in this period, airway management among mechanically ventilated neonates is crucial in preventing VAP.[9,10]

Ventilator associated pneumonia is pneumonia that develops at or later than 48 hours after the neonate has been placed on mechanical ventilation till 48 hours after extubation.[9] It is the second most common hospital acquired infection among pediatric intensive care units (PICUs) and NICUs. Generally, it can be divided into two categories; early onset VAP occurring within the first 4 days of intubation and late onset VAP, occurring after 5 days of intubation.[9,10]

Throughout childhood, the greatest risk of death from pneumonia is obvious particularly among neonates. It is estimated that pneumonia is responsible for 750000 to 1.2 million neonatal deaths annually, accounting for 10% of global child mortality.[11,12] The most recent National Nosocomial Infection Surveillance (2007) in the United States of America reported that VAP in NICU ranged from 1.4 to 3.5 per 1000 ventilator days and its incidence rate ranged from 10-70% in neonates depending on the studied population and the diagnostic criteria.[9] On the national level, VAP is a leading cause of morbidity and mortality in NICUs. It is reported to be the highest among preterm neonates. This was recorded in Alexandria statistical records of NICU in **El Shatby Materntity University Hospital.** It registered that the incidence of VAP was 29.6 per 1000 ventilator days in the year 2011.[13]

Mechanically ventilated neonates are at risk for retained secretions from many causes. Endotreacheal intubation impairs the body's upper airway defense system. It allows direct entry of bacteria to the lower part of the respiratory tract by impairing the cough reflex, interfering with mucociliary escalator and predisposing the neonate to infection, which increases the volume and tenacity of mucus.[5-8] As accumulation of endotracheal secretions is common in mechanically ventilated neonates, the principle goal of airway management is to establish and maintain a patent airway in order to ensure adequate alveolar ventilation and oxygenation. Thus, tracheal suctioning (TS) is periodically warranted in intubated neonates. It reduces the work of breathing, stimulates cough reflex whenever it is impaired, prevents pulmonary aspiration of blood and gastric fluids and prevents infection.[14,15]

Tracheal suctioning is described as a component of bronchial hygiene that involves mechanical aspiration of pulmonary secretions. It is usually performed through open suction system (OSS) where the neonate is disconnected from the ventilator and the suction catheter is introduced into the endotracheal tube (ETT). Although TS is a necessary intervention in the care of intubated neonate, it is not a benign one. It is associated with various complications such as hypoxemia, cardiac arrhythmia, nosocomial respiratory tract infection, pneumonia, trauma and atelectasis. Nosocomial respiratory tract infection and pneumonia are considered two of the most serious complications associated with suctioning.[16,17]

Tracheal suction has been implicated in the development of VAP as the result of mobilization of bacteria colonizing the tracheal tube into the respiratory tract by insertion of suction catheter or instillation of normal saline during suctioning. Mucosal trauma of the lower trachea caused by deep suctioning may also enhance tracheal bacterial colonization and then promote pneumonia. Moreover, contaminated suctioning equipments including suction catheter play a role in the incidence of VAP.[18,19]

Closed suction system (CSS) has been introduced into clinical practices with the aim of preventing or reducing the unwanted effects of OSS. During CSS, the neonate can be suctioned without disconnection from the ventilator. So, the risk of complications such as hypoxemia and nosocomial respiratory tract infection may be reduced by minimizing the interference with ventilation during the procedure. CSS has also been proposed as a part of a program for prevention of VAP. [9,20,21]

The NICU nurse has a fundamental role in achieving optimal health status without subjecting the neonate to complications. Mechanically ventilated neonates are highly dependent on skilled nurses throughout all aspects of their health care. The most important one of such aspects is the ability to maintain a patent airway attained by tracheal suctioning procedure. One of the challenges facing the NICU nurse when dealing with intubated neonate is to achieve a balance between ensuring a patent airway by tracheal suctioning and preventing nosocomial respiratory tract infection. [3,21-23]

There are currently no recommendations of Center of Disease Control (CDC) regarding the preferential use of closed or open suction system in neonates. Unfortunately, studies comparing between closed and open suction systems in mechanically ventilated neonates are limited. [21-23] Therefore, this study was conducted to evaluate the effect of closed versus open suction system on the occurrence of VAP in neonates.

Aim of the Study

The aim of this study is to determine the effect of closed versus open suction system on the occurrence of ventilator associated pneumonia in neonates.

Hypothesis

Neonates who are suctioned by open suction system exhibit ventilator associated pneumonia more than neonates who are suctioned by closed suction system.

2. Materials and Method

Materials

Research Design:

A quasi experimental design was used to accomplish the study.

Setting:

The study was conducted at the Neonatal Intensive Care Unit (NICU) of El- Shatby Maternity University Hospital in Alexandria.

Subjects

A convenient sample of 50 mechanically ventilated neonates were selected. They were chosen within the first 24 hours from initiation of ventilatory support. The neonates were randomly assigned into two groups. Twenty five neonates were suctioned by closed suction system, and the other 25 neonates were suctioned by open suction system. Neonates of both groups were chosen alternatively.

Tools

Four tools were used to collect the needed data.

Tools for data collection were developed by the researcher after thorough review of related literature. They comprised the following:

Tool I: Neonate's Physiological Parameters:

The tool was developed to assess neonate's characteristics and physiological parameters. It included the following data:

A: Characteristics of the neonates such as age, sex, birth weight, gestational age, type of delivery, date of admission, diagnosis on admission and date of starting mechanical ventilation.

B: Neonate's physiological parameters such as temperature, heart rate, respiratory rate, oxygen saturation and blood pressure.

Tool II:

Ventilator Associated Pneumonia Observation Check List:

The tool was developed for diagnosing VAP. It included the following:

- New onset of purulent sputum.
- Change in sputum character e.g. color, amount and consistency.
- Retraction of chest.

Tool III: Chest Assessment Check List:

Chest assessment tool was developed to determine development of VAP which included the following:

- Presence of adventitious sounds.
- Excessive respiratory secretions requiring frequent suctioning.

Tool IV: Diagnostic Measures Sheet:

This tool was used to confirm diagnosis of VAP. It comprised the following:

1- **Lab investigation:** value of WBCs was obtained from neonate's chart.
2- **Report of chest radiograph** including new or progressive infiltrates and presence of consolidation.

3- Non bronchoscopic bronchoalveolar lavage (NB- BAL):

Non bronchoscopic bronchoalveolar lavage performed by the pediatrician for bacteriological confirmation of clinical diagnosis and the results was obtained from the report.

Method

1- An official approval for conducting the study was obtained from the responsible administrative personnel after explaining the aim of the study.
2- Tools of the study were developed after thorough review of the related literature.
3- Content validity of the tools was done by five experts in the pediatric nursing field and recommended changes were done.
4- Before conducting the study, informed consent was obtained from parents after explaining the aim of the study. Parents were assured that confidentiality will be guaranteed.
5- A pilot study was carried out on 5 neonates to test the applicability of the tools. Those neonates were excluded from the study.
6- Subjects were assigned into two groups namely group "A" and group "B". Group A was suctioned by closed suction system and group B was suctioned using open suction system. Neonates of both groups were chosen alternatively.
7- Initially, data concerning characteristics and physiological parameters of each neonate in both groups were assessed using tool I.
8- Thereafter, reassessment of the physiological parameters was carried out for 3 consecutive days.
9- Parameters of the ventilator were monitored to evaluate neonate's ventilatory demands and oxygen requirement.

10- **Suction considerations were performed for both groups as follows:**

- Suction was done for both groups as needed.
- Negative suction pressure was 60-80mmHg.
- Hyperoxygenation of the neonates was performed before suction through the ventilator by increasing FIO^2 by 10-20% above the baseline data.[1]
- After suction, FIO^2 was gradually decreased to the pre suction level.
- Three suction passes only were applied during each suctioning intervention. Each suction pass was limited to a maximum period of 10-15 sec.
- Negative suction pressure was applied intermittently and only during catheter withdrawal.

11- **Closed endotreacheal suctioning method was done under aseptic technique as follows:**

- The breathing circuit of the ventilator and endotracheal tube were connected to the closed suction connectors.
- The suction catheter was continuously placed between the endotracheal tube and Y piece of the ventilator.
- The proximal end of the suction valve was connected to the suction device after removing the protection cap.
- To perform suctioning, the catheter was rotated in an anti clockwise direction.
- The suction catheter was advanced gradually inside the endotracheal tube **without disconnection** from the ventilator .
- The suction valve upper button was pressed to activate vacuum and suction the secretions. To stop suctioning, the valve button was released.

- Upon completion of the suctioning, the suction catheter was pulled back until the distal tip **black marking ring** was fully visible inside the protective sleeve, indicating that the catheter is fully withdrawn from the airway.
- The catheter was closed by rotating it at clockwise direction.
- To flush the suction catheter, a syringe with sterile water was connected to the flushing line, suction valve was activated to set vacuum and simultaneously inject washing sterile water.

12- Open endotreacheal suctioning method was done under aseptic technique as follows:
- The endotracheal tube was **disconnected** at Y piece of the ventilator during suctioning.
- By using dominant thumb and forefinger the suction catheter was inserted into the endotracheal tube gently and quickly without applying suction. Suction was applied only on withdrawal of the catheter.
- Reconnection of the neonate to the ventilator.

13- Each neonate in both groups was assessed for development of clinical criteria of VAP for 4 consecutive days starting from initiation of ventilatory support using tool II.

14- Chest assessment was performed for each neonate in both groups using tool III to assess the presence of adventitious chest sounds.

15- Laboratory evidences of WBCs were recorded for each neonate in both groups using tool IV.

16- Chest radiograph was done and recorded daily. New or progressive lung infiltrate suggesting VAP was confirmed by the pediatrician using tool IV.

17- Data was analyzed and interpreted to indicate VAP using neonatal clinical criteria for diagnosing VAP based on the recommendation of **CDC** which include: [9]
- The neonate must have **worsening gas exchange** in the form of oxygen desaturation, increase oxygen requirement or increase ventilatory demands and at **least three** of the following criteria:
- Temperature instability.
- New onset of purulent sputum or change of the sputum character.
- Excessive respiratory secretions requiring frequent suctioning.
- Apnea, tachypnea .
- Nasal flaring with retraction of chest or grunting.
- Wheezing or rales.
- Bradycardia (heart rate < 100 b/m) or Tachycardia (heart rate >170 b/m).
- Leucopenia (WBCs < 4000 cells/mm^3) or leukocytosis (WBCs > 15000 cells/mm^3)

18- Neonates of both groups who were clinically diagnosed as VAP were further subjected to NB-BAL procedure for bacteriological confirmation of clinical diagnosis.

19- Non bronchoscopic bronchoalveolar lavage was done by the pediatrician.

20- Comparison between two groups was done to evaluate the effect of closed versus open suction system on the occurrence of ventilator associated pneumonia.

3.Results

Table (I) illustrates the biological characteristics of the studied neonates. Male neonates constituted 56% of those among the closed suction group compared to 64% of those who were suctioned by the open suction system. As regards gestational age, it was clear that the majority of neonates among both groups were preterm neonates (88% of the closed suction group and 92% of the open suction group).

The same table reveals that age of 60% of neonates among the closed suction group and 68% among those of the open suction group was less than 24 hours old. It was also clear from the table that 68% of neonates of the closed suction group were delivered by cesarean section compared to 84% of those of the open suction group. Concerning the birth weight, it was observed that 28% of both groups were very very low birth weight neonates. It was obvious that biological characteristics of neonates of both groups were more or less similar without any statistical significant differences.

Table (II) portrays the distribution of neonates among the closed and open suction groups according to their diagnosis on admission. It was observed that, 48% of neonates among the closed suction group and 56% of those among the open suction group were suffering from respiratory distress syndrome and congenital pneumonia.

Table (III) describes the clinical criteria for diagnosing VAP among neonates of the closed suction group. It was clear from the table that, none of those neonates had oxygen desaturation (i.e oxygen saturation less than 95%) on the first 24 hours of the initiation of ventilatory support. This percent increased to 8% and 24% on the second and the third day respectively, while on the fourth day such percent has reached 36%. Statistical significant differences were found between the first & the third day ($^{FET}P = 0.022$) as well as between the first & the fourth day ($^{FET}P=0.022$).

Moreover, on the first day almost half of the neonates (48%) had FIO_2 more than 60%. This percent declined to half fold (24%) on the second day. Further decrease to only 20% was observed on the third day, while on the fourth day, such percent of neonates was elevated to 36%.The relation between the first and the third day was statistically significant where ^{FET}P= 0.037.

It was also recognized that equal percent of neonates (8%) of the closed suction group were hypothermic i.e their body temperature was less than 36.5 C^0 on the first and the third day. This percent increased to 12% on the fourth day. On the other hand, 4% of neonates suffered from hyperthermia i.e their body temperature was higher than 37.5 C^0 on the third and the fourth day.

Concerning the heart rate, tachycardia (i.e heart rate more than 170 b/m) was present among small proportions of neonates on the second, third and fourth day of the study period (4%, 8% and 12% respectively).

Regarding the respiratory rate, it was apparent that nearly one quarter of the neonates (24%) were presented with tachypnea i.e respiratory rate was more than 60c/m on the first day. This percentage slightly increased to 28% on the second day, whereas it declined to 16% and 12% on the third and the fourth day respectively.

Studying chest retractions among neonates of the closed suction group, it was clear from the same table that all neonates (100%) experienced chest retraction on the first and the second day. The percentage slightly decreased to 88% and 76% on the third and fourth day respectively. There was statistical significant difference between the first & the fourth day (^{FET}P = 0.022).

In relation to presence of adventitious sounds, the table portrayed that slightly less than two thirds of neonates (64%) had adventitious sounds on the first day. Such percent was increased to 72% on the second day, while it dropped again to 64% on the third day and 60% on the fourth day.

Purulent sputum started to appear on the second day of ventilatory support where it was detected among 20% of neonates. This percent increased to 40% and 44% on the third and the fourth day respectively. There were statistical significant differences between the first & the second day (^{FET}P= 0.0501), the first & the third day (^{X2}P =0.0004) and the first & the fourth day (^{X2}P = 0.0002).

The table also showed that, only 8% of neonates exhibited change of the sputum consistency on the first day. Meanwhile, the percent was raised to 40 % and 68% on the second and the third day respectively. Further increase was observed among nearly three quarters of neonates (72%) on the fourth day. Statistical significant differences were found between the first & the second day (^{X2}P= 0.008), the first & the third day (^{X2}P <0.0001) and the first & the fourth day (^{X2}p<0.0001).

Concerning increase in the amount of secretions, it was found that 24% of neonates exhibited increase in the amount of secretions on the first day. On the second day, this percentage was increased among more than half of them (56%). Further increase was observed on the third day where, 72% of neonates had increased amount of secretions. On the other hand, the percent slightly declined to 68% on the fourth day. Statistical significant differences were found between the first & the second day (^{X2}P= 0.021), the first & the third day (^{X2}P=0.0007) and the first & the fourth day (^{X2}p=0.002).

The table also revealed that, about one quarter of neonates (24%) required suctioning more than 4 times per day on the first day. This percent increased to 32% and 48% on the second and the third day respectively. On the fourth day, the percent of neonates who needed frequent suctioning dropped to 40%.

In relation to W.B.Cs count, it was found that none of the neonates had leucopenia (i.e W.B.Cs less than 4000 cell/ mm^3) throughout the four days of the study period. On the other hand, neonates who had leukocytosis (i.e W.B.Cs more than 15000 cell/ mm^3) constituted 28% on the first day, 16% on the second day and 12% on the third and the fourth day respectively.

Table (IV) shows the clinical criteria for diagnosing VAP among neonates of the open suction group. It was clear from the table that, only 12% of neonates had oxygen desaturation (oxygen saturation less than 95%) during the first 24 hours of the initiation of ventilatory support. The percentage of oxygen desaturation among those neonates was increased throughout the second, third and fourth day (20%, 52% and 60% respectively). Statistical significant differences were found between the first & the third day as well as between the first& the third day as well as between the first & the fourth day (^{X2}P= 0.002 and ^{X2}P=0.0002 respectively).

Studying FIO^2 of neonates related to such group, it was observed on the first day that the percentage of FIO^2 among nearly one quarter of the neonates (24%) was more than 60%. This percent dropped to 16% on the second day, while it increased to 32% and 56% on the third and the fourth day respectively. A statistical significant difference was detected between the first and the fourth day (^{X2}P=0.021)

Regarding the incidence of hypothermia (i.e body temperature less than 36.5^0 C), the table revealed that 8% of neonates had hypothermia on the first day. This percent dropped to 4% on the second day, while it increased equally to 24% on the third and the fourth day.

Concerning the heart rate, it was recognized that small proportions of neonates suffered from tachycardia (i.e heart rate more than 170 b/m) on the first and second day (4% and 8% respectively). This percent increased to 28% on the third day, while it decreased to only 4% on the fourth day. The difference was statistically significant between the first & the third day ($^{FET}P= 0.049$).

As regards the respiratory rate, the same table showed that equal percent of neonates (28%) had tachypnea (i.e respiratory rate was more than 60c/m) on the first and the second day from initiation of the ventilatory support. These percentages decreased to 20% and 16% on the third and the fourth day respectively.

Chest retractions were apparent among all neonates (100%) of the open suction group during the first and the second day of the study period. Slight decrease of the percent was observed among 88% of neonates on the third and the fourth day with no statistical significant difference.

Furthermore, the table revealed that percentage of those presented with adventitious chest sounds had reached 20% and 48% on the first and the second day respectively. This percentage jumped to 64% and 60% on the third and the fourth day respectively with statistical significant differences between the first &the second day ($X^2p= 0.037$), the first & the third day ($X^2P= 0.002$) and the first &the fourth day ($X^2p= 0.004$).

Regarding the presence of purulent sputum, it was apparent that none of the neonates of the open suction group had purulent sputum on the first day, while it started to appear among 32% of them on the second day. On the other hand, purulent sputum appeared vigorously on the third and the fourth day (56% and 72% respectively). There were statistical significant differences between the first & the second day ($^{FET}P = 0.023$), the first & the third day ($^{X2}p< 0.0001$) and the first &the fourth day ($^{X2}P <0.0001$).

Moreover, it was obvious that 20% of the neonates exhibited change of sputum consistency on the first day. The percent was raised among more than half of the neonates (56%) on the second day, while it jumped to 72% on the third and the fourth day. There were statistical significant differences between the first & the second day ($^{X2}P=0.009$), the first &the third day ($^{X2}P=0.0003$) and the first &the fourth day ($^{X2}p=0.0003$).

Following the increase of the amount of secretions throughout the study, the same table illustrated that, about one quarter of the neonates (24%) exhibited increase in the amount of secretions on the first day. This increase has reached higher percentages on the second, third and fourth day (60% 76% and 84% respectively). Again, there were statistical significant differences between the first & the second day ($X^2P=0.009$), the first &the third day ($X^2P=0.0002$) and the first &the fourth day ($X^2p<0.0001$).

The table also reflected that, secretions of 16% of neonates were suctioned more than 4 times per day on the second day, while this percent jumped to 56% and 60% on the third and the fourth day respectively. There were statistical significant differences between the first & the third day ($X^2P<0.0001$) and the first & the fourth day ($X^2p<0.0001$).

Finally, the table showed that, none of the neonates suffered from leucopenia i.e W.B.Cs less than 4000 cell/ mm3 on the first day, while 4% of them had leucopenia on the second day. This percentage increased to 12% and 24% on the third and the fourth day respectively. There was a statistical significant difference between the first and the fourth day ($^{FET}P=0.022$). On the other hand, 12% of neonates had leukocytosis (i.e W.B.Cs more than 15000 cell/ mm3) on the first day. This percentage increased equally to 20% on the second and the third day. Further increase to 24% was observed on the fourth day.

Table (V) compare between neonates of the closed and open suction groups regarding clinical criteria for diagnosing VAP. The base line data on the first day revealed no statistical significant difference between both groups regarding oxygen desaturation. Further assessment on the fourth day showed that 60% of neonates of the open suction group had oxygen desaturation compared to only 36% of those related to the closed suction group with statistical significant difference ($^{X2}P=0.048$).

Concerning the presence of adventitious chest sounds, it was clear that 64% of neonates of the closed suction group had adventitious chest sounds compared to 20% of neonates of the open suction group on the first day with statistical significant difference between both groups ($X^2P =0.002$).On the other hand, an equal percent of neonates of both groups (60%) had adventitious chest sounds on the fourth day.

As expected, none of the neonates among both groups suffered from purulent sputum within the first 24 hours of intubation. Meanwhile, on the fourth day only 44% only of neonates of the closed suction group had purulent sputum compared to 72% of those joining the open suction group. The relation was statistically significant between the two groups on the fourth day ($^{X2}P=0.045$).

The same table revealed that, 24% of neonates of the closed suction group required frequent suctioning compared to none of those related to the open suction group on the first day and the relation was statistically significant (^{FET}P= 0.022). On the other hand, 60% of those in the open suction group required frequent suctioning compared to only 40% of neonates of the closed suction group on the fourth day with no statistical significant difference.

None of the neonates of both groups had leucopenia on the first day. On the fourth day, 24% of neonates of the open suction group had leucopenia compared to none of the neonates of the closed suction group. Statistical significant difference was found between both groups (^{FET}P=0.022).

Table (VI) compares between neonates of the closed and open suction groups regarding the occurrence of clinical VAP. It was clear from the table that, clinical VAP was present among 36% of neonates of the closed suction group compared to 60% of neonates of the open suction group. There was statistical significant difference between both group (^{X2}P= 0.047).

Table (VII) clarifies the findings of chest radiography among neonates of the closed and open suction groups. It was apparent from the table that, radiological evidence showed lung infiltrate among 64% of neonates of the open suction compared to only 24% of neonates of the closed suction group. Statistical significant difference existed between both groups (^{Mc}P= 0.009).

Table (VIII) clarifies the findings of Non-bronchoscopic bronchoalveolar lavage culture among neonates who developed clinical VAP among the closed and open suction groups. It was found that 55.6% of neonates of the closed suction group had positive NB-BAL culture compared to 80% of neonates of the open suction group with no statistical significant difference.

Table (IX) exhibits the isolated organisms from NB-BAL culture among neonates of the closed and open suction groups. It was obvious that Klebsiella was the most prominent micro-organism of NB-BAL cultures among both groups, where it was present among 60% of neonates of the closed suction group and 66.6% of neonates of the open suction group. Acinitobacter was also observed among 20% of NB-BAL culture of neonates of the closed suction group compared to 33.3% of neonates of the open suction group.

Table (I): Biological Characteristics of the Studied Neonates.

Biological Characteristics	Closed Suction (n=25)		Open Suction (n=25)		Significance
	No.	%	No.	%	
1. Sex					
• Male	14	56	16	64	X^2=0.333 P=0.564
• Female	11	44	9	36	
2. Gestational age					
• Preterm	22	88	23	92	^{FET}P=1.0
• Term	3	12	2	8	
3. Age on admission					
• Less than 24 hours	15	60	17	68	^{MC}P=0.917
• 24 hours	6	24	4	16	
• More than 24 hours	4	16	4	16	
4. Type of delivery					
• Normal delivery	8	32	4	16	X^2=1.754 P=0.185
• Cesarean section	17	68	21	84	
5. Birth weight in grams					
• Very very low birth weight (<1000gm)	7	28	7	28	^{MC}P=0.092
• Very low birth weight (<1500gm)	9	36	2	8	
• Low birth weight (<2500gm)	6	24	12	48	
• Normal birth weight(≥2500gm)	3	12	4	16	
Total	25	100	25	100	

MC: Monte Carlo Test X^2: Chi-Square Test FET: Fisher's Exact Test *significant at P≤0.05

Table (II): Distribution of Neonates among the Closed and Open Suction Groups According to their Diagnosis on Admission.

Diagnosis on admission	Closed Suction (n=25)		Open Suction (n=25)		Significance
	No.	%	No.	%	
• Respiratory distress syndrome	8	32	6	24	^{MC}P=0.581
• Congenital pneumonia	2	8	4	16	
• Respiratory distress syndrome & congenital pneumonia	12	48	14	56	
• Others➢	3	12	1	4	
Total	25	100	25	100	

MC: Monte Carlo Test *significant at P≤0.05 Others➢: Convulsion, Hypoglycemia.

Table (III): Clinical Criteria for Diagnosing VAP among Neonates of the Closed Suction Group.

Clinical criteria for Diagnosing VAP#	Closed Suction (n=25)								Significance between 1st & 2nd day	Significance between 1st & 3rd day	Significance between 1st & 4th day
	1st day		2nd day		3rd day		4th day				
	No	%	No	%	No	%	No	%			
• Oxygen saturation less than 95%	0	0	2	8	6	24	9	36	^{FET}P=0.489	**^{FET}P=0.022***	**^{FET}P=0.022***
• FIO_2 more than 60%	12	48	6	24	5	20	9	36	X^2=3.13 P=0.077	**X^2=4.37 P=0.037***	X^2=0.74 P=0.39
• Temperature less than 36.5^{0}C	2	8	0	0	2	8	3	12	^{FET}P=0.489	^{FET}P=1.0	^{FET}P=1.0
• Temperature higher than 37.5^{0}C	0	0	0	0	1	4	1	4	^{FET}P=1.0	^{FET}P=1.0	^{FET}P=1.0
• Heart rate more than170 b/m	0	0	1	4	2	8	3	12	^{FET}P=1.0	^{FET}P=0.489	^{FET}P=0.235
• Respiratory rate more than 60c/m	6	24	7	28	4	16	3	12	X^2=0.1 P=0.747	X^2=0.5 P=0.479	^{FET}P=0.463
• Chest retractions	25	100	25	100	22	88	19	76	^{FET}P=1.0	^{FET}P=0.235	**^{FET}P=0.022***
• Presence of adventitious sounds	16	64	18	72	16	64	15	60	X^2=0.37 P=0.544	X^2=0.0 P=1.0	X^2=0.08 P=0.771
• Presence of purulent sputum☆	0	0	5	20	10	40	11	44	**^{FET}P=0.0501***	**X^2=12.5 P=0.0004***	**X^2=14.1 P=0.0002***
• Change of sputum consistency	2	8	10	40	17	68	18	72	**X^2=7.02 P=0.008***	**X^2=19.1 P<0.0001***	**X^2=21.33 P<0.0001***
• Increased amount of secretions	6	24	14	56	18	72	17	68	**X^2=5.33 P=0.021**	**X^2=11.54 P=0.0007***	**X^2=9.74 P=0.002***
• Frequency of suction (more than 4 times/ day)	6	24	8	32	12	48	10	40	X^2=0.4 P=0.529	X^2=3.13 P=0.078	X^2=1.47 P=0.225
• WBCs less than 4.000 cell/mm^3	0	0	0	0	0	0	0	0	-	-	-
• WBCs more than 15.000 cell/mm^3	7	28	4	16	3	12	3	12	X^2=1.05 P=0.306	X^2=0.5 P=0.479	X^2=0.5 P=0.479

X^2: Chi-Square test FET: Fisher's Exact test FIO_2: Fraction Inspired Oxygen; ☆ Purulent sputum: yellow / brown secretions
*significant at P≤0.05; #Clinical Criteria for diagnosing VAP are not mutually exclusive.

Table (IV): Clinical Criteria for Diagnosing VAP among Neonates of the Open Suction Group.

Clinical Criteria for Diagnosing VAP#	Open Suction (n=25)								Significance between 1st & 2nd day	Significance between 1st & 3rd day	Significance between 1st & 4th day
	1st day		2nd day		3rd day		4th day				
	No	%	No	%	No	%	No	%			
• Oxygen saturation less than 95%	3	12	5	20	13	52	15	60	^{FET}P=0.702	**X^2=9.19 P=0.002***	**X^2=14.35 P=0.0002***
• FIO_2 more than 60%	6	24	4	16	8	32	14	56	X^2=0.5 P=0.479	X^2=0.4 P=0.529	**X^2=5.33 P=0.021***
• Temperature less than 36.5^{0}C	2	8	1	4	6	24	6	24	^{FET}P=1.0	^{FET}P=0.247	^{FET}P=0.247
• Temperature higher than 37.5^{0}C	1	4	0	0	0	0	0	0	^{FET}P=1.0	^{FET}P=1.0	^{FET}P=1.0
• Heart rate more than 170 b/m	1	4	2	8	7	28	1	4	^{FET}P=1.0	**^{FET}P=0.049***	^{FET}P=1.0
• Respiratory rate more than60c/m	7	28	7	28	5	20	4	16	X^2=0.0 P=1.0	X^2=0.44 P=0.508	X^2=1.05 P=0.306
• Chest retractions	25	100	25	100	22	88	22	88	^{FET}P=1.0	^{FET}P=0.235	^{FET}P=0.235
• Presence of adventitious sounds	5	20	12	48	16	64	15	60	**X^2=4.37 P=0.037***	**X^2=9.93 P=0.002***	**X^2=8.33 P=0.004***
• Presence of purulent sputum☆	0	0	8	32	14	56	18	72	**^{FET}P=0.023***	**X^2=16.1 P<0.0001***	**X^2=24.53 P<0.0001***
• Change of sputum consistency	5	20	14	56	18	72	18	72	**X^2=6.88 P=0.009***	**X^2=13.61 P=0.0003***	**X^2=13.61 P=0.0003***
• Increased amount of secretions	6	24	15	60	19	76	21	84	**X^2=6.65 P=0.009***	**X^2=13.52 P=0.0002***	**X^2=18.12 P<0.0001***
• Frequency of suction (more than 4 times/ day)	0	0	4	16	14	56	15	60	^{FET}P=0.109	**X^2=19.44 P<0.0001***	**X^2=21.43 P<0.0001***
• WBCs less than 4.000 cell/mm^3	0	0	1	4	3	12	6	24	^{FET}P=1.0	^{FET}P=0.109	**^{FET}P=0.022***
• WBCs more than15.000 cell/mm^3	3	12	5	20	5	20	6	24	^{FET}P=0.702	^{FET}P=0.702	^{FET}P=0.463

X^2: Chi-Square test FET: Fisher's Exact test FIO_2: Fraction Inspired Oxygen ☆ Purulent sputum: yellow / brown secretions
*significant at P≤0.05 #Clinical Criteria for diagnosing VAP are not mutually exclusive.

Table (V): Clinical Criteria for Diagnosing VAP among Neonates of the Closed and Open Suction Groups on the 1st and the 4th Day.

Clinical Criteria for Diagnosing VAP#	1st day					4th day				
	Closed Suction (n=25)		Open Suction (n=25)		Significance	Closed Suction (n=25)		Open Suction (n=25)		Significance
	No.	%	No.	%		No.	%	No.	%	
• Oxygen saturation less than 95%	0	0	3	12	$^{FET}P=0.235$	9	36	15	60	**$X^2=3.92$ $P=0.048$***
• FIO_2 more than 60%	12	48	6	24	$X^2=3.13$ $P=0.077$	9	36	14	56	$X^2=2.01$ $P=0.156$
• Temperature less than 36.5^{0}C	2	8	2	8	$^{FET}P=1.0$	3	12	6	24	$^{FET}P=0.463$
• Temperature higher than 37.5^{0}C	0	0	1	4	$^{FET}P=1.0$	1	4	0	0	$^{FET}P=1.0$
• Heart rate more than170 b/m	0	0	1	4	$^{FET}P=1.0$	3	12	1	4	$^{FET}P=0.609$
• Respiratory rate more than 60b/m	6	24	7	28	$X^2=0.1$ $P=0.747$	3	12	4	16	$^{FET}P=1.0$
• Chest retractions	25	100	25	100	$^{FET}P=1.0$	19	76	22	88	$^{FET}P=0.463$
• Presence of adventitious sounds	16	64	5	20	**$X^2=9.93$ $P=0.002$***	15	60	15	60	$X^2=0.0$ $P=1.0$
• Presence of purulent sputum☆	0	0	0	0	$^{FET}P=1.0$	11	44	18	72	**$X^2=4.02$ $P=0.045$***
• Change of sputum consistency	2	8	5	20	$^{FET}P=0.417$	18	72	18	72	$X^2=0.0$ $P=1.0$
• Increased amount of secretions	6	24	6	24	$X^2=0.0$ $P=1.0$	17	68	21	84	$X^2=1.75$ $P=0.185$
• Frequency of suction (more than 4 times/ day)	6	24	0	0	**$^{FET}P=0.022$***	10	40	15	60	$X^2=2.0$ $P=0.157$
• WBCs less than 4.000 cell/mm^3	0	0	0	0	-	0	0	6	24	**$^{FET}P=0.022$***
• WBCs more than 15.000 cell/mm^3	7	28	3	12	X2=0.5 P=0.479	3	12	6	24	$^{FET}P=0.463$

X^2: Chi-Square test ^{FET}P: Fisher's Exact test ☆Purulent sputum: yellow / brown secretions FIO_2: Fraction Inspired Oxygen *significant at $P\leq0.05$

Table (VI): Occurrence of Clinical VAP among Neonates of the Closed and Open Suction Groups.

Occurrence of Clinical VAP	Closed Suction (n=25)		Open Suction (n=25)		Significance
	No.	%	No.	%	
• Clinical VAP	9	36	15	60	**$X^2=3.945$ $P=0.047$***
• No VAP	16	64	10	40	
Total	25	100	25	100	

X^2: Chi-Square test *significant at $P\leq0.05$

Table (VII): Findings of Chest Radiography among Neonates of the Closed and Open Suction Groups.

Chest Radiological Findings	Closed Suction (n=25)		Open Suction (n=25)		Significance
	No.	%	No.	%	
• No infiltrate	19	76	9	36	**$^{MC}P=0.009$***
• Infiltrate	6	24	16	64	
Total	25	100	25	100	

MC: Monte Carlo Test *significant at $P\leq0.05$

Table (VIII): Findings of Non-Bronchoscopic Bronchoalveolar Lavage Culture of Neonates Developing Clinical VAP among the Closed and Open Suction Groups.

NB-BAL Culture ☆	Clinical VAP				Significance
	Closed Suction (n=9)		Open Suction (n=15)		
	No.	%	No.	%	
• **Positive**	5	55.6	12	80	$^{FET}P=0.208$
• **Negative**	4	44.4	3	20	
Total	9	100	15	100	

FET: Fisher's Exact Test *significant at $P\leq0.05$ NB-BAL☆: Non-bronchoscopic bronchoalvelor lavage

Table (IX): Isolated Organisms from Non-Bronchoscopic Bronchoalveolar Lavage Culture among Neonates of the Closed and Open Suction Groups.

Micro-organisms#	Closed Suction (n=5)		Open Suction (n=12)	
	No.	%	No.	%
• Klebsiella	3	60	8	66.6
• Acinitobacter	1	20	4	33.3
• Citrobacter	1	20	2	16.6
• Pseudomonas	0	0	2	16.6
• E-Coli	0	0	3	25
• Enterococcus fecalis	0	0	1	8.3
• Staphylococcus aureus	0	0	1	8.3

#Micro- organisms are not mutually exclusive.

4. Discussion

Unfortunately, mechanical ventilation is associated with a substantial risk of VAP in NICUs. Dramatically, it increases morbidity and mortality rates and is considered the most common infectious complication among neonates admitted to NICUs.(9,24,25)

Bacterial colonization of the aero-digestive tract as well as aspiration of contaminated secretions into the lower respiratory airway are thought to be involved in the pathogenesis of VAP. Presence of ETT helps bacteria to travel from the oropharynx to the lower respiratory tract. In addition, the presence of ETT reduces efficacy of the natural defense mechanisms of the upper respiratory airway, hence allows access of microorganisms to the lower respiratory airways.(10,26,27)

Clearance of secretions is an essential part of care provided for mechanically ventilated neonates. Therefore, tracheal suctioning is mandatory for those neonates to ensure good ventilation and oxygenation. Although necessary, this procedure causes a series of complications such as hypoxemia, hemodynamic instability and VAP development. (26-28)

Currently there are two types of tracheal suctioning, the open system which requires neonate disconnection from the ventilator circuit and the closed system which does not require disconnection. (26,27) Although preliminary studies reported that CSS reduced the risk of developing VAP, the comparative effectiveness over OSS for prevention of VAP remains controversial.(29) Therefore, this study was carried out to determine the effect of closed versus open suction system on the occurrence of VAP in neonates.

Biological characteristics of neonates in the present study reflected that the majority of the studied neonates among both groups were suffering from respiratory distress syndrome (Table II). This result could be attributed to the fact that respiratory distress syndrome affects mainly the preterm neonates (Table I). This happened because they are born early and therefore do not benefit from surfactant material that help support the respiratory system. These findings are supported by several researchers who reported that respiratory distress syndrome occurs usually in neonates less than 35 weeks of gestation. It also represents a major problem in NICUs and is considered the primary cause of neonatal mortality.(1,30,31)

Lack of gold standard for VAP diagnosis is still a problem facing neonatologists. Clinical diagnosis of VAP may be applied inconsistently, as the lack of specificity of some criteria such as; oxygen desaturations, increase oxygen requirements and increased ventilator demand may exacerbate this problem.(9) Moreover, lack of specificity of chest radiographs may lead to over diagnosis and unnecessary use of antibiotics. Hence, it is recommended that chest radiographs must be carefully reviewed by expert neonatologists to rule out other possible diagnosis common in NICUs, such as hyaline membrane disease, meconium aspiration and atelectasis. This emphasizes the importance of the bacteriological confirmation of the clinical and radiological diagnosis, and so accurately estimating the true magnitude of VAP. (32,33)

The current study revealed that, diagnosis of VAP was established by clinical criteria, radiological evidence and bacteriological confirmation. Results of the present study clarified that clinical diagnosis of VAP among neonates of both groups was based on the presence of worsening gas exchange in the form of oxygen desaturation and increase oxygen requirement. Both are considered to be among the main indicators of VAP development. Such results explained that, neonates of the open suction group experienced a significant increase in capillary oxygen desaturation and FIO_2 more than neonates of the closed suction group on the second, third and fourth day (Table III, IV). This could be attributed to the fact that during the process of OSS, gas drawn from the lungs was replaced by air drawn from the atmosphere through the space left around the catheter which intern decreases the oxygen saturation and enhances the entrance of microorganisms.[34] In addition, modification of ventilation and perfusion ratio induced by OSS may lead to frequent impairment of oxygen saturation.[35] This result is similar to the results of **Bader et.al (2011)** who reported that signs of worsening gas exchange were present among all neonates with clinical VAP. [36]

Moreover, the incidence of hypothermia was more apparent among neonates of the open suction group than those of the closed suction group particularly on the third and fourth day (table III, IV). A study carried out in Saudia Arabia by **Afify et.al (2012)** showed similar findings, where they reported that VAP was significantly associated with the presence of hypothermia.[37] This could be justified by the fact that hypothermia is one of the early signs of fighting infections in neonates rather than hyperthermia due to the immaturity of thermoregulation center.[30,31]

Craig (2002) ascertained the importance of neonatal chest assessment because it will help detect any leading sign to VAP development. Accordingly, she mentioned that the presence of adventitious sounds is considered a main criterion for an obstructed airway and presence of pneumonia.[38] Findings of the current study confirmed the previously mentioned fact. Percentages of neonates presented with adventitious sounds were increased throughout the four days of the study period among neonates of the open suction group with statistical significant difference. On the other hand, the percentages of those presented with adventitious sounds among the closed suction group were increased on the second day while a drop of such percentages was observed on the third and the fourth day (Table III, IV). This clarifies that the use of CSS was better than the use of OSS as CSS provides adequate removal of secretions that may obstruct the airway. In addition, the presence of adventitious sounds may be related to diagnosis of the studied neonates on admission and intubation. These findings are supported by **Khamis et.al (2011)** who reported that adventitious sounds were decreased by using CSS more than OSS in ventilated neonates with statistical significant differences.[39]

The presence of purulent secretions in ETT suctioning is a very suggestive sign in neonates diagnosed with clinical VAP. Several studies reported that purulent tracheal secretions were significantly present among neonates diagnosed with VAP.[33,40,41] The findings of the present study reflected that purulent sputum started to appear on the second day among both groups. On the other hand, it appeared vigorously on the third and the fourth day among neonates of the open suction group more than among those of the closed suction group (Table III,IV). This results are in agreement with **Ba-Alwi (2008)** who reported that mucopurlent secretions were increased among the open suction group compared to those of the closed suction group.[42] These findings could be interpreted in the light of the fact that ETT provides a surface for pathogenic organisms from the gastrointestinal tract and oropharynx and provides direct access for those organisms into the lower respiratory tract.[43] Furthermore, increased manipulation of OSS during the process of disconnection and reconnection may give rise to aspiration of contaminated secretions into the lower respiratory airway.

In USA, **Cordero et.al (2000)** studied the effect of closed versus open endotracheal suction system on small premature neonates. They reported that neonates of the open suction group required frequent suctioning per day more than neonates of the closed suction group.[44] This is congruent with the current study findings where, the percent of neonates who required frequent suctioning per day was low among those receiving closed suctioning on the fourth day compared to those of the open suction group with no statistical significant difference (Table V). This could be justified by the fact OSS can increase cross contamination by ambient micro-organisms due to frequent disconnection which may result in excessive secretion formation.

Chest radiography was used for radiological diagnosis of VAP in the present study. It was observed that neonates of the open suction group developed radiological evidence of pneumonia more than neonates of the closed suction group with statistical significant difference (Table VII).This result is in accordance with **Bader et.al (2011),**who reported that chest radiographs were diagnostic in all neonates clinically diagnosed as VAP.[36] This similarity could be explained by the fact that radiological diagnosis of VAP was based on the presence of new or progressive lung infiltrate 48hours after ventilation.[32]

It was observed from the current study that, neonates who were suctioned by closed suction system experienced less VAP development than neonates of the open suction system with statistical significant difference (table VI). This could be explained by the fact that CSS prevents exogenous contamination, while OSS facilitates neonatal lung contamination because of being disconnected from the ventilator. Furthermore, increased manipulation of ventilator circuit and its attachment during OSS could be viewed as an additional predisposing factor for VAP development. This is thought to occur by increasing the occurrence of aspiration of contaminated secretion or tubing condensate.[45-48]

The previously mentioned results are in harmony with **Cordero et. al. (2000),** who reported that CSS decreases the rate of VAP and obviates the need for ventilator disconnection. They also reported that CSS is well accepted by nurses because it is less time consuming. It is also better tolerated by small premature neonates requiring mechanical ventilation for one week or more.(44) Moreovere, a German meta-analysis of randomized controlled trials done by **Vonberg et.al (2006)** about the impact of open versus closed suction system on the incidence of VAP reported that closed suction system is ready for prompt use. So, less time is required to begin the procedure. Thus, risk of cross contamination between neonates and staff by ambient microorganisms is minimized because the system is only disconnected once or less per day.(49) In addition, a study done by **Rudnov et. al (2007)** revealed that closed system may reduce colonization and lower respiratory tract infection with significant decrease the risk of pneumonia.(50)

On the other hand, findings of the present study contradicts findings of a study carried out by **Lorente et.al (2006)** about tracheal suction by closed system without daily change versus open system. They reported that no statistical significant differences were found concerning the incidence of VAP among both groups. They also concluded that the use of the closed system without routine complete daily change and maintaining the suction catheter as clean as possible did not increment development of VAP compared to the use of open system.(28) Furthermore, a Turkey prospective randomized controlled trial done by **Topeli et.al (2004)** concluded that CSS resulted in increased colonization rates of ventilator tubing with micro-organisms but did not increase the development of VAP compared to OSS.(47) Such contradiction between the latter study and the results of the current study could be attributed to the difference of VAP diagnostic criteria where Topeli used cardiopulmonary infection score and ventilator tubing culture, while the current study followed CDC criteria in addition to NB-BAL culture for diagnosing VAP.

The accuracy and safety of NB-BAL has been confirmed by few studies among neonates. Furthermore, the microscopic examination of NB-BAL fluid helps differentiate between tracheobronchial colonization and infection, while culturing the tip of the ETT could be misleading as it usually does not isolate the organisms present in the lung.(41,51)

Results of NB-BAL culture in the current study pointed out gram negative bacteria e.g. Klebsiella and Acinitobacter as the most evident isolated organisms of VAP among both groups (Table IX). Yet, NB-BAL culture in the present study documented that Klebsiella was the most prominent cause of VAP affecting neonates of both groups with higher percentage among neonates of open suction group. This result is in agreement with **Tayel (2009)** who conducted a study about incidence of VAP in NICU of El Shatby Maternity University Hospital in Alexandria. This study reported that, gram negative bacteria was isolated from the majority of neonates and Klebsiella was predominating positive NB-BAL culture.(52) Moreover, a study done by **Cordero et.al (2000)** reported that, airway colonization with gram negative bacteria occurred in the majority of the open suction group compared to the closed suction group and the differences were statistically significant.(44)

The previously mentioned findings could be attributed to the aspiration of micro-organisms colonizing the oropharynx. The oropharynx becomes colonized with aerobic gram negative bacteria within few days of admission. Therefore, VAP is caused predominantly by gram negative bacilli that may enter the lower airway in mechanically ventilated neonates.(53) In addition, neglecting mouth care may contribute to oral colonization of pathogenic bacteria.(18) Moreover, **Steven et.al (2010)** reported that oral secretions may become subglottic secretions that pool above the endotracheal tube and lead to microaspiration of secretions to the lower respiratory tract.(54) Furthermore, gram negative bacilli which are able to survive and multiply in moist environment may colonize ventilation equipment such as ventilator circuits and humidifiers which consequently deliver contaminated air directly into the respiratory air way. Lastly, contaminated hands or respiratory equipments with gram negative bacteria may be considered as other possible sources of bacteria entering the lower airway.(18)

The present study also revealed that Acinitobacter is considered the second causative agent of VAP among neonates of the open suction group. This is in line with **Mansour and Bendary (2012)** who reported that Klebsiella was the most important cause of VAP followed by Acinitobacter.(55) Furthermore, a study carried out in Turkey by **Koksal et.al (2006)** reported that, Acinitobacter was the most predominating causative agent of VAP in neonates.(41) These results could be attributed to the ability of Acinitobacter to survive on healthcare workers' hands and environmental surfaces in addition to its intrinsic resistance to many common antibiotics.(55)

On the other hand, a surveillance carried out during the period between 2002 to 2007 in ICUs of Latin America, Asia, Africa, and Europe, using CDC criteria for diagnosing VAP, revealed higher rates of VAP with gram positive infection compared to that found in the United States ICUs.(56) This can be explained by the fact that distribution of micro-organisms differs from one NICU to another. It also, differs within the same place from one period of time to another.

Conclusion

Based on the findings of the present study, it can be concluded that neonates of the open suction group experienced ventilator associated pneumonia more than those of the closed suction group. Moreover, the growth of the isolated organisms from NB-BAL cultures among neonates of the closed suction group was less than among those of the open suction group.

Recommendations

Based on the previous findings, the following recommendations are suggested:

- Closed suction catheters should be available in NICUs especially for neonates with high PEEP or high frequency ventilator.
- All NICUs should be provided with updated polices related to closed suction system.
- In-service training programs regarding benefits and utilization of closed suction catheter should be conducted for NICU nurses.
- It is mandatory for NICU nurse to attend refreshing courses and/or workshops regarding updated theoretical and clinical aspects of infection control.
- Comprehensive updated evidence based guidelines for VAP prevention must be strictly followed in NICUs.
- Comprehensive updated evidence based guidelines concerning endotreacheal suctioning must be strictly followed in NICUs.

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12/22/2013