Research Article

PAEDIATRIC NONBRONCHOSCOPIC BRONCHOALVEOLAR LAVAGE: OVERVIEW AND RECOMMENDATIONS FOR CLINICAL PRACTICE

ABSTRACT: NB-BAL is an effective procedure for the diagnosis of pulmonary disease processes in ventilated infants and children. This procedure is, however, not without risks to both patients and staff. Numerous complications of NB-BAL exist, with hypoxia being the most common. As a result, care should be taken in performing NB-BAL on haemodynamically unstable patients; patients with coagulation defects; and patients with cardiac or brain abnormalities.

This paper presents an overview of paediatric nonbronchoscopic bronchoalveolar lavage (NB-BAL) including: the rationale for NB-BAL; the complications associated with the procedure; indications and contraindications. It also recommends an evidence-based clinical guideline for performing the procedure in the paediatric intensive care unit.

By following the NB-BAL guidelines presented in this paper, one can ensure that an effective specimen is obtained from the lower respiratory tract, whilst minimising the risk to the patient.

KEY WORDS: NONBRONCHOSCOPIC BRONCHOALVEOLAR LAVAGE; PAEDIATRIC; INTENSIVE CARE; CLINICAL GUIDELINE.

INTRODUCTION

Diagnostic nonbronchoscopic bronchoalveolar lavage (NB-BAL) is a procedure performed by physiotherapists in paediatric intensive care units both locally (Morrow et al 2004; Morrow and Argent 2001) and internationally (Burmester and Mok 2001). Despite this, there are currently no published NB-BAL protocols in physiotherapy journals.

This paper aims to present the rationale behind paediatric NB-BAL; the complications associated with the procedure; and it recommends an evidence-based NB-BAL protocol including indications, contraindications and technique, for use in the paediatric intensive care unit.

RATIONALE

Diagnosis of aetiological agents in childhood pneumonia is difficult as blood culture results are frequently negative (Grigg et al 1993). Tracheal aspirate cultures have relatively low sensitivity and are unreliable in most intubated patients due to contamination with organisms colonising the upper respiratory tract (Jourdain et al 1995).

HIV/AIDS is the leading cause of death among young South African children (Bradshaw et al 2003). *Pneumocystis jiroveci* pneumonia is an important opportunistic infection in immunocompromised patients, and in the South African context this a particular concern in HIV-infected patients. *Pneumocystis jiroveci* cysts typically adhere to Type I alveolar cells. As NB-BAL specifically samples the alveolar lining, this tool has become increasingly important in the diagnosis of *Pneumocystis jiroveci* pneumonia in immunocompromised patients (Panero et al 1995).

Bronchoscopic BAL requires expensive equipment and a large amount of operator training and expertise. Bronchoscopic BAL in infants is limited by endotracheal tube (ETT) size as the commonly available 3.5mm paediatric bronchoscope largely obstructs the lumen of ETT < 4.5mm internal diameter (Koumbourlis and Kurland 1993, Alpert et al 1992) and smaller bronchoscopes have no suction channel.
Nonbronchoscopic bronchoalveolar lavage (NB-BAL) was first described in a paediatric population by Alpert et al (1992). It is a simple, effective, less time-consuming procedure that requires less expertise and is cheaper than bronchoscopic BAL (Prokop et al 1996, Pugin et al 1991, Minotuli et al 1990, Mann et al 1987, Caughey et al 1985). In addition, there where is diffuse disease, direct visualisation by bronchoscopy is not necessary. NB-BAL is able to sample fluid specifically from the lower respiratory tract, as demonstrated by the presence of alveolar macrophages in the lavage fluid. Diagnostic yields from 42% to 85% have been reported (Morrow and Argent 2001, Kourisbournlis and Kurland 1993, Alpert et al 1992, Minotuli et al 1990, Piperno et al 1988).

In addition to the diagnostic benefits, therapeutic benefits of NB-BAL have also been described. It was found to be effective in improving lung expansion in 84% of infants with radiological evidence of lobar collapse, which had not responded to conventional chest physiotherapy (Galvis et al, 1994). Dargaville et al (1999) noted that in three infants with meconium aspiration NB-BAL appeared to have a beneficial effect by removing meconium debris. Kourisbournlis and Kurland (1993) also observed that two patients with atelectasis showed radiological evidence of improvement following NB-BAL.

**NB-BAL COMPLICATIONS:**

There are reports of nursing staff acquiring tuberculosis (TB) from children requiring endotracheal suctioning (Curtis et al 1999, Rabalais et al 1991), implying a potential risk of infection to the therapist performing NB-BAL. Appropriate infection control precautions should therefore always be taken, particularly in the South African context where infectious diseases such as TB are particularly rife (Zar et al 2005, Shingadia and Novelli 2003).

Early studies of paediatric NB-BAL reported no clinically significant patient complications (Schindler and Cox 1994, Kourisbournlis and Kurland 1993, Alpert et al 1992, Minotuli et al 1990, Piperno et al 1988). The majority of these initial studies did not report oxygenation or ventilation requirements or document arterial blood gases. One cannot, therefore, conclude from them that NB-BAL is safe in extremely sick, unstable children and infants. Subsequent studies have highlighted potentially serious adverse effects of paediatric NB-BAL (Morrow et al 2004a, Morrow and Argent 2001, Burmester and Mok 2001). It must be noted that studies investigating the complications of paediatric NB-BAL have excluded patients with raised intracranial pressure, haemodynamic instability and coagulation disorders (Morrow et al 2004a, Morrow and Argent 2001) due to the potential complications identified from data relating to endotracheal suctioning (Darlow et al 1997, Alpert et al 1992, Singh et al 1991, Perlman and Volpe 1983, Anderson and Chandra 1976).

Hypoxia, which is a frequent complication of NB-BAL, is mild and self-limiting in most cases (Morrow et al 2004a, Burmester and Mok 2001, Morrow and Argent 2001, Dargaville et al 1999, Baughman and Conrad 1998). However, in some cases prolonged severe episodes of hypoxia have been reported, with the patient requiring escalation of oxygen and ventilatory support (Morrow et al 2004a, Morrow and Argent 2001, Burmester and Mok 2001). NB-BAL-induced hypoxia may be caused by a combination of: i) oxygen deprivation if the oxygen supply is disconnected; ii) interruption of ventilation with an associated decrease in airway pressure (Maggio et al, 2003); iii) airway occlusion by the suction catheter (Morrow et al 2004a); iv) aspiration of intrapulmonic gas during prolonged suctioning (Ehrhart et al, 1981); v) the effect of the lavage itself (Ridling et al 2003, Burmester and Mok 2001); and vi) coughing.

During NB-BAL, the catheter remains in the tracheobronchial tree, thus partially obstructing the airway and markedly increasing airway resistance, for longer periods than during normal endotracheal suctioning. It is likely that the added airway obstruction caused by the suction catheter could also cause carbon dioxide retention. For the purposes of NB-BAL, repeated suction manoeuvres are performed without allowing recovery time. This repeated application of negative pressure may lead to loss of lung volume with resulting hypoxia (Morrow et al 2004a, Morrow et al 2004b, Simbruner et al 1981, Rosen and Hillard 1962). A large amount of saline is instilled into the lungs during NB-BAL. The volume of saline introduced into the lungs during the procedure may decrease the available surface area for gaseous exchange and unretrieved saline could interfere with alveolo-capillary oxygen exchange (Ridling et al 2003). It is interesting to note that in many experimental models of acute lung injury, the injury is induced by means of saline lavage (Allen et al 2002, Rimensberger et al 1999, Neumann et al 1998).

Burmester and Mok (2001) were unable to identify predictive factors for NB-BAL complications. Dargaville et al (1999) were unable to demonstrate a propensity for desaturation based on severity of lung disease. In contrast to these studies, Morrow and Argent (2001) and Morrow et al (2004a) demonstrated that there is a significantly greater risk of more marked and more prolonged desaturation in patients with high oxygenation indices and low PaO2/FiO2 (partial pressure of oxygen / fraction of inspired oxygen) ratios, as seen in patients with acute respiratory distress syndrome and acute lung injury.

Cardiac arrhythmia with significant desaturation followed by death has been reported in a child undergoing bronchoscopic BAL with pulmonary hypertension and congestive heart failure secondary to upper airway obstruction (Wagener 1987). It was postulated that hypoxia-induced increased pulmonary vascular resistance could precipitate worsening heart failure. In addition, when there is pulmonary hypertension in the presence of high pulmonary vascular pressure, markedly negative intrapleural pressures during partially obstructed aspiration may result in fluid transudation from the pulmonary vessels thereby precipitating acute pulmonary oedema (Wagener 1987). Bye et al (1987) reported serious side effects of bronchoscopic BAL in two patients: one patient had a seizure and another experienced increased tachypnoea and low BAL fluid return and died 30 hours after the procedure.
These authors mention the potential risk of fluid overload as a result of poor recovery of BAL fluid.

Prolonged, clinically significant changes in blood pressure requiring escalation of inotropic support have been reported following NB-BAL (Burmester and Mok 2001). Bronchial haemorrhage has been observed following nonbronchoscopic protected brush specimens and bronchoalveolar lavage (Morrow and Argent 2001, Labenne et al 1999). Diagnostic BAL in patients with pneumonia may cause intravascular translocation of toxins or mediators, producing pyrogenic and hypotensive effects (Pugin and Suter 1992, Labenne et al 1999).

Pneumothorax has been reported as a complication of NB-BAL in neonates (Labenne et al 1999). Pneumothorax is a particular risk of NB-BAL as the suction catheter is passed far beyond the ETT into the bronchi themselves (Anderson and Chandra 1976).

On application of negative suction pressure, most of the instilled saline is removed along with some of the alveolar lining fluid, which contains surfactant necessary for the patency and stability of the alveoli (Burmester and Mok 2001). This may result in atelectasis with subsequent hypoxia. As a result of the concern about washing out of surfactant it has been suggested that NB-BAL may exacerbate existing respiratory disease, particularly in infants with neonatal Respiratory Distress Syndrome. However, in a controlled trial, repeated NB-BAL in newborn infants did not appear to be associated with radiological changes suggesting that surfactant was not consistently removed (Kotecha 1999).

INDICATIONS AND CONTRAINDICATIONS


It is suggested that specific indications for NB-BAL should include radiological or clinical evidence of lung disease, raised infectious markers and a deteriorating clinical picture despite optimal management. It is felt that NB-BAL should ideally be performed on stable patients as soon after intubation as possible, before bacterial endotracheal tube colonisation has occurred and/or in the event of a changing clinical picture with signs of infection and unknown pathogen. The contraindications and precautions to NB-BAL, based on the complications discussed previously, are listed in the insert below.

Considering the high diagnostic yield of NB-BAL, it may be worth the risk of performing the procedure in certain high-risk patients despite the presence of contraindications, where there have been no other positive cultures. These patients, however, should be selected carefully. Consideration should be given to the risk: benefit ratio for the child, the financial cost of the investigations, and how NB-BAL findings would influence patient management.

It is recommended that special precautions be taken with regard to sedation, level of preoxygenation and technique during NB-BAL in patients with high oxygenation and ventilation requirements, particularly in patients with oxygenation indices >10, ventilation indices >20 and with PaO2/ FiO2 <150 (Morrow and Argent 2001).

Bronchoscopic BAL (which allows direct visualisation of the airways) is indicated where there is localised lung disease and ETT >4,5mm internal diameter. This is preferable as specific sampling from the area of pathology can be obtained. In infants with small ETT internal diameters, and unilateral lung disease, directed blind NB-BAL can be performed by positioning the patients with their head away from abnormal lung (Kotecha 1999).

The potential complications of NB-BAL should not be minimised. All patients should be carefully monitored throughout the procedure (Pattishall et al 1988) and resuscitation equipment should be available at all times.

PAEDIATRIC NB-BAL TECHNIQUE

Numerous NB-BAL techniques have been reported (Burmester and Mok 2001, Dargaville et al 1999, Koumbourlis and Kurland 1993, Alpert et al 1992). Based on these, and other studies, Morrow et al (2004a) describe a simple, effective NB-BAL technique which maintains ventilation throughout the procedure and effectively reduces the number of complications, specifically that of desaturation. This method is effective, inexpensive, and easy to perform and is therefore the recommended NB-BAL technique. A detailed description of the technique is presented in the series of boxed inserts:

**CONTRAINDICATIONS OR PRECAUTIONS TO PAEDIATRIC NB-BAL**

- Haemodynamic instability
- Pulmonary haemorrhage.
- Pulmonary oedema.
- Cor pulmonale with pulmonary hypertension.
- Raised intracranial pressure.
- Congestive cardiac failure.
- Coagulopathy, with platelet count <50 x 10^9/l. NB-BAL may be considered after transfusion of blood products if the coagulopathy has resolved.
- Neonatal respiratory distress syndrome, due to the concern about washing out of surfactant.
- Premature, small-for-gestational-age infants due to the risk of intraventricular haemorrhage.
- NB-BAL is not appropriate after a decision has been made to withdraw ventilatory support, offer palliative care or limit invasive and unpleasant procedures.
2. According to clinical indications, the specimen may be sent for microscopy, 1. The second and third aliquot together are sent to the laboratory. 2. Electrocardiographical and pulse oximetry monitoring must be used throughout. 3. A manual resuscitation bag, with oxygen flow turned on, should be ready at the patient’s side. 4. Preoxygenate with 100% inspired oxygen for approximately one minute prior to NB-BAL and maintain this FiO₂ throughout until the patient’s oxyhaemoglobin saturation (SaO₂) returns to prelavage levels. 5. Remove pressure probe or seal at ventilator port and place two layers of Tegaderm transparent dressing (3M Health Care, USA) over the aperture to seal the ventilator system. Pierce the Tegaderm with a needle.

**NB-BAL PROCEDURE**

1. Pass a suction catheter of appropriate size through the Tegaderm, into the ETT; wedge the catheter as far distally as possible and then withdraw very slightly (<0.5cm). The catheter should not have side-holes in order to facilitate delivery of saline to the distal air spaces beyond the point of wedging and to minimise mucosal trauma caused by the adherence of the side-holes to the bronchial walls (Morrow et al 2004, Dargaville et al 1999).
2. Introduce the first lavage volume of 1ml per kg body weight of 0.9% saline at room temperature, through the catheter. It has been suggested that by adjusting BAL volume to body weight, a constant fraction of epithelial lining can be obtained (Ratjen and Bruch 1996).
3. Attach the suction catheter to a mucus extractor with wall unit suction applied. One obtains a better fluid return with continuous pump suction than with intermittent manual aspiration (Caughey et al 1985).
4. Continue suctioning until no more saline is withdrawn. Movement of the catheter of about 5mm is permissible to maximise fluid return.
5. Two further lavages of 1ml/kg body weight of saline solution are performed through the same catheter in the same position. The catheter is not withdrawn in between suction events.
6. The first aliquot is discarded, and the subsequent two are collected in the same mucus extractor and sent for analysis (Ratjen and Bruch 1996, Grigg et al 1993). The cell profile of the first aliquot differs from the subsequent two, containing mainly bronchial cellular material and epithelial cells. Separation of the first portion of the aspirated fluid may thus improve information gained about lower respiratory tract pathology (Pohunek et al 1996).
7. If a patient’s SaO₂ drops to < 81% at any stage during the procedure the catheter should be withdrawn immediately while attempting to suction as much fluid back as possible in the process. If immediate improvement does not occur, the patient should be manually ventilated with 100% oxygen until SaO₂ returns to pre-lavage levels (Morrow et al 2004).

**PNB-BAL PROCESSING**

1. The second and third aliquot together are sent to the laboratory. 2. According to clinical indications, the specimen may be sent for microscopy, culture and sensitivity; viral culture; TB studies; extended fungal culture; Pneumocystis jiroveci immunofluorescence; and histology for any or all of cytology, fat laden macrophages, haemosiderin laden macrophages and viral inclusion bodies.

**CONCLUSION:**

This paper presents an overview of the reasons for performing diagnostic NB-BAL; the complications associated with the procedure; and it recommends an evidence-based NB-BAL protocol for use in the paediatric intensive care unit.

NB-BAL is an effective procedure for the diagnosis of pulmonary disease processes in ventilated infants and children. This procedure is, however, not without risks to both patients and staff. Numerous complications of NB-BAL exist, with hypoxia being the most common. As a result, care should be taken in performing NB-BAL on haemodynamically unstable patients and patients with coagulation defects, cardiac or brain abnormalities.

By following a defined protocol, one can ensure that the most effective specimen is obtained from the lower respiratory tract, whilst minimising the risk to the patient.

**REFERENCES**


Bradshaw D, Bourne D, Nannan N 2003 What are the leading causes of death among South African children? MRC Policy Brief No. 3, December

Burmester M, Mok Q 2001 How safe is non-bronchoscopic bronchoalveolar


Ridling DA, Martin LD, Bratton SL 2003 Endotracheal Suctioning With or Without Instillation of Isotonic Sodium Chloride Solution in Critically Ill Children. American Journal of Critical Care 12: 212 - 219


CHECK OUT THE SASP’S WEBSITE AT www.physiosa.org.za

TO ADVERTISE IN THE SOUTH AFRICAN JOURNAL OF PHYSIOTHERAPY, CONTACT AMERICO AT SASP HEAD OFFICE:
Tel: (011) 485-1467, Fax: (011) 485-1613 E-mail: pr@saphysio.co.za

ARTICLES FOR THE SOUTH AFRICAN JOURNAL OF PHYSIOTHERAPY:
All articles must be submitted in an electronic format directly to the Editor:
Prof CJ Eales,
P.O. Box 356 Mossel Bay 6500 Email: eales@icon.co.za