Wall-mounted versus handheld syringe suction for pediatric bronchoalveolar lavage: A Randomized controlled trial

Aruna Herath[1], Kana Jat[1], Rakesh Lodha[2], Venkateswaran Iyer[2], Jayati Sarangi[1], and Sushil Kabra[1]

[1]All India Institute of Medical Sciences
[2]All India Institute Of Medical Sciences, New Delhi

June 1, 2020

Abstract

Background: Bronchoalveolar lavage (BAL) via flexible bronchoscopy is a valuable diagnostic technique in children. The quality of BAL is directly related to the volume of the fluid recovered. Continuous wall suctioning and the handheld syringe suctioning are the two commonly used methods, but they are rarely compared in children. We aimed to compare the above two suctioning techniques for BAL in the pediatric age group. Methods: This randomized controlled study enrolled children of age one month to 18 years of age undergoing flexible bronchoscopy and BAL. We compared continuous wall suctioning and the handheld syringe suctioning technique. The primary outcome was the percentage of BAL fluid recovery in two different suctioning techniques. Secondary outcomes included technical acceptable BAL and yield of various diagnostic tests in BAL. Results: The study included 73 children (48 boys) with a median (IQR) age of 30 (8, 108) months. There were 37 children in wall mount group and 36 children in syringe suction group. The baseline characteristics of the groups were similar. The wall mount suction had more recovery of BAL fluid compared to the syringe method (43.6±8.4% vs 37.8±8.5%, p-value 0.004). The proportion of BAL having fluid recovery of [?]40% was also high in wall mount suction [31 (83.8%) vs 17 (47.2%); p-value 0.001]. There was no difference in diagnostic yield between the groups. Conclusion: Wall mount suction had better BAL fluid recovery compared to handheld syringe suction in children undergoing flexible bronchoscopy. The diagnostic yield was similar in both groups.

Wall-mounted versus handheld syringe suction for pediatric bronchoalveolar lavage: A Randomized controlled trial

Aruna H, Kana Ram Jat, Rakesh Lodha, Venkateswaran K Iyer[1], Jayati Sarangi[1], SK Kabra

Department of Pediatrics and Department of Pathology[1]

All India Institute of Medical Sciences, New Delhi-110029, India

Correspondence:

Kana Ram Jat

Department of Pediatrics

All India Institute of Medical Sciences, New Delhi-110029, India

Email: drkanaram@gmail.com

Authors' contribution : KRJ and SKK: has the concept of study; AH: enrolled patients and collected data; AH and KRJ: wrote the manuscript; VKI and JS: performed cytology; RL and SKK: revised the manuscript

with intellectual input; all authors approve the final version of the manuscript; KRJ will act the guarantor of the manuscript.

Funding: None.

Conflict of interest: None.

Short running title: Wall-mounted versus handheld syringe suction for pediatric bronchoalveolar lavage.

The trial is registered at Clinical Trial Registry of India (CTRI) with number CTRI/2018/11/016243. It can be assessed at: ctri.nic.in/Clinicaltrials/showallp.php?mid1=28884&EncHid=&userName=Wall mounted suction versus handheld syringe suction for pediatric bronchoalveolar lavage.

Wall-mounted versus handheld syringe suction for pediatric bronchoalveolar lavage: A Randomized controlled trial

Abstract:

Background: Bronchoalveolar lavage (BAL) via flexible bronchoscopy is a valuable diagnostic technique in children. The quality of BAL is directly related to the volume of the fluid recovered. Continuous wall suctioning and the handheld syringe suctioning are the two commonly used methods, but they are rarely compared in children. We aimed to compare the above two suctioning techniques for BAL in the pediatric age group. Methods: This randomized controlled study enrolled children of age one month to 18 years of age undergoing flexible bronchoscopy and BAL. We compared continuous wall suctioning and the handheld syringe suctioning technique. The primary outcome was the percentage of BAL fluid recovery in two different suctioning techniques. Secondary outcomes included technical acceptable BAL and yield of various diagnostic tests in BAL. Results: The study included 73 children (48 boys) with a median (IQR) age of 30 (8, 108) months. There were 37 children in wall mount group and 36 children in syringe suction group. The baseline characteristics of the groups were similar. The wall mount suction had more recovery of BAL fluid compared to the syringe method (43.6±8.4% vs 37.8±8.5%, p-value 0.004). The proportion of BAL having fluid recovery of [?]40% was also high in wall mount suction [31 (83.8%) vs 17 (47.2%); p-value 0.001]. There was no difference in diagnostic yield between the groups. Conclusion: Wall mount suction had better BAL fluid recovery compared to handheld syringe suction in children undergoing flexible bronchoscopy. The diagnostic yield was similar in both groups.

Keywords: Bronchoalveolar lavage, flexible bronchoscopy, children, wall mount suction, handheld syringe suction.

The trial is registered at Clinical Trial Registry of India (CTRI) with number CTRI/2018/11/016243. It can be assessed at: ctri.nic.in/Clinicaltrials/showallp.php?mid1=28884&EncHid=&userName=Wall mounted suction versus handheld syringe suction for pediatric bronchoalveolar lavage.

Introduction

Bronchoalveolar lavage (BAL) via flexible bronchoscopy is a commonly used and valuable diagnostic technique in children with various respiratory disorders.[1,2] In fact, it is the most frequent invasive respiratory investigation performed by pediatric respiratory physician worldwide to recover a specimen that can represent the cellular and the acellular composition at the epithelial cell lining fluid of the distal airway and alveolar surface.[1,2]The quality of the obtained sample and the success of the procedure is directly related to the volume of the BAL fluid recovered.[2] There is marked variation in performing bronchoscopy and BAL in children among various centres .[1,3–6] The mode of suctioning during BAL is one of the main factors which potentially affect the fraction of the fluid recovery during the procedure. Continuous wall suctioning

and the handheld syringe suctioning are the two commonly used methods described in the adult and the pediatric practice.[7],[8] Handheld syringe suctioning can be done directly through the working channel of the bronchoscopy using the same syringe used to instil the BAL fluid.[9] Although BAL is commonly used in the pediatric pulmonology, prospective studies done to compare above two BAL fluid recovery techniques are lacking in the literature. One retrospective study in children reported better BAL fluid recovery with syringe technique compared to wall mount suction.[7] Whereas one study in animals reported better BAL fluid recovery using suction pump aspiration compared to manual syringe aspiration.[10]Two randomized controlled trials (RCT) compared handheld syringe and wall mount technique for BAL fluid recovery and reported different results.[11,12] Even ERS task force didn't recommend one technique over the other in their guidelines for BAL in children.[2] The performing BAL in children is different from adults because of using small bronchoscope with a smaller working channel and a limited amount of instilled fluid that can be used. There is always a need to standardize the technique of BAL in children. There is hardly any RCT comparing the two techniques in children. Our objective was to compare the above two suctioning techniques (wall mounted versus handheld syringe technique) for BAL in the pediatric age group.

Methodology

We performed a randomized controlled trial in the Pediatric Pulmonology Division of the Department of Pediatrics, at a tertiary care centre in North India between August 2018 to January 2019. Inclusion criteria were children of age one month to 18 years undergoing flexible bronchoscopy and BAL. Based on a study by Rosas-Salazar et al[7], the handheld technique had 7% better yield. To achieve 80% power and 0.05 significance level, the estimated sample size was 70 in each group (a total of 140 children).

Randomization, allocation concealment, and blinding

We did randomization using computer-generated random numbers with variable block size. It was performed by a person, not involved in the trial. Random numbers were kept in serially numbered sealed opaque envelopes for allocation concealment. We opened envelope only after talking informed consent. There was no blinding because of obvious nature of interventions.

Intervention

We enrolled eligible children after receiving written informed consent from parents. A consultant pediatric pulmonologist did bronchoscopy. It was done under conscious sedation using intravenous (IV) midazolam and fentanyl with additional local anaesthetic cover using lidocaine spray as we go. We did bronchoscopy via transnasal route using Olympus video bronchoscope with an external diameter of 3.8 mm with 1.2 mm working channel. We did BAL from Right middle lobe unless the pathology was found to be localized to another lobe depending on the radiological and the bronchoscopic findings. We monitored children throughout and after the procedure for any complications. Two aliquots of 1 ml /kg sterile normal saline were injected after wedging the distal end of the scope to the suitable lobar or segmental bronchus. After each aliquot of saline, 2 ml of air was injected to empty the working channel of the bronchoscope. The third aliquot of 1 ml/kg was used if the total retrieved BAL was less than 5 ml. The instilled fluid was aspirated immediately without any dwelling time by using one of following two techniques: **Group 1 (wall mount suction)** : The saline aliquot was instilled through bronchoscope working channel using an appropriate size syringe, and we aspirated it via the suction channel of bronchoscope utilizing a wall-mounted suction apparatus and a mucus trap interposed. The negative pressure of the wall suctioning device was set to 100-200 mmHg depending on the age (towards the lower end in young children and higher-end in older children) of the child at the beginning of the procedure. The pressure was adjusted during the procedure if there was an airway collapse. In the case of visible bronchial collapse, the fluid recovery was achieved by a frequent short burst of suctioning or partial compression of the suction valve to deliver less negative pressure without altering the pre-set wall suction pressure.**Group 2 (handheld syringe suction)** : the required amount of saline was injected through the working channel of the bronchoscope using 10 ml, 20 ml or 50 ml syringe

as appropriate and we re-aspirated via the same syringe just after injection without any dwelling time. We manipulated syringe suctioning pressure during the procedure depending on the degree of visible bronchial collapse. In each group, the primary goal was to aspirate maximum BAL fluid volume after each aliquot. At the end of the procedure, all two or three aliquots were pooled into a plastic container before measuring the total fluid return. After that, BAL was sent for investigations as indicated by clinical condition.

Data collection

We recorded demographic data (age, sex, height, weight), clinical indication for the bronchoscopy, relevant general and respiratory system examination findings, radiology and other related investigation findings in the predesigned data collection form. We recorded the total amount of fluid aspirated and reports of BAL investigations.

The primary outcome was the percentage of BAL fluid recovery in two different suctioning techniques, namely continuous wall suctioning and manual syringe suctioning directly through the working channel of the bronchoscope in children. The secondary outcomes were: (1) total cell count and differential count in each mode of suctioning technique; (2) proportion of procedures having technically acceptable BAL in each mode of suctioning ($>$ 40% fluid recovery); and (3) positivity of microbiological tests (Gram stain, bacterial culture, KOH study, fungal culture, Gene Xpert and MGIT culture for tuberculosis, pneumocystis jiroveci, and cytomegalovirus) in each mode of suctioning.

The BAL fluid for cytopathology analysis were grouped into three categories: (1) Infective conditions: BAL done for tuberculosis or other infections; study compared the percentage of neutrophils in BAL in both the groups; (2) BAL done for clinically and/or radiologically suspected aspiration pneumonia; study compared the percentage of lipid-laden macrophages in both the groups; (3) BAL for suspected interstitial lung disease; we compared the percentage of macrophages, eosinophils and other cell types in both the groups.

For cytology, BAL samples were centrifuged at 1700 rpm for five minutes, followed by cytospin preparation at 1000 rpm for 3-4 minutes. We prepared three slides each for Papanicolaou, May-Grunwald-Giemsa and Ziehl-Neelsen stain. If clinically needed, we made additional smears for Oil Red O, iron stain and others.

On microscopic examination, the samples were categorized as 0 (zero)- unsatisfactory (smears with blood obscuring morphology or artefacts of preservation and processing making interpretation difficult); 1- low cellularity (very low cell count based on a subjective evaluation); 2- good cellularity (numerous alveolar macrophages or acute inflammatory exudate with epithelial cells forming between 5-10% of all cells); and 3- very good cellularity (numerous alveolar macrophages or acute inflammatory exudate with epithelial cells less than 5% of all cells). BAL fluids with an acute inflammatory reaction were placed in category 2 and 3, and less importance was given to the presence of alveolar macrophages as long as it was over 10%.

We compared BAL cellularity between the syringe and wall-mounted suction groups. We considered category 0 and 1 poor cellularity and 2 and 3 as good cellularity of BAL.

Institute ethics committee approved the trial, and it was registered at the Clinical Trial Registry of India (CTRI) with number CTRI/2018/11/016243.

Statistical analysis

We analyzed data using Stata version 12.0 (College Station, TX: StataCorp LP) We presented continuous data as mean with SD if normally distributed or as median with IQR if not normally distributed. Categorical data were presented as a percentage. We compared the volume of BAL fluid recovered between both groups using t-test, Mann-Whitney test, chi-square/Fisher exact test as appropriate.

Results

We screened 88 children undergoing flexible bronchoscopy during the study period. Eight children didn't meet the inclusion criteria and were excluded. The remaining 80 children were randomized. Out of these seven children didn't undergo BAL and were excluded from the study. The study included 73 children (48 boys) with median (IQR) age of 30 (8, 108) months. The average amount of saline instilled and retrieved was 22.7+-9.0 ml and 9.0+-3.7 ml, respectively, in all subjects. The mean+-SD percentage of fluid recovery for the whole group was 41.9+-10.6%. There were 37 children in wall mount suction group and 36 children in syringe suction group (Figure 1).

The baseline characteristics between the wall mount and handheld syringe suction group are shown in Table 1. There was no difference in baseline characteristics, including an indication of bronchoscopy, findings on bronchoscopy and site of BAL procedure (Table 1). In the wall suction group, 5 (13.5%), 23 (62.2%), and 9 (24.3%) children received 200, 250 and 300 cm H_2O negative pressure, respectively. In handheld syringe group, 25 (69.4%) received suction using 20 ml syringe, and 11 (30.6%) received suction using 50 ml syringe.

Table 2 shows the results of the primary and secondary outcome of the study. The percentage retrieval was significantly higher in wall mount suction compared to syringe suction (Figure 1). Overall, 48 (65.7%) children had percentage retrieval of $> 40\%$, and it was significantly higher in wall mount suction compared to syringe suction (Table 2).

We sent BAL fluid for KOH study, fungal culture, tuberculosis work-up and a few special stains as clinically indicated. Table 3 shows the results of these special investigations. We didn't compare the results of these special investigations between the syringe and wall mount suction groups because there was a minimal positivity rate. There were no significant complications in any of the child included in the study.

Discussion

In probably first such RCT in children, we compared wall mount and handheld syringe suction technique in children undergoing flexible bronchoscopy and BAL. The wall mount suction technique was better in retrieving more BAL fluid. The diagnostic yield of BAL was not different between the groups.

Flexible bronchoscopy guided BAL is being used worldwide in children including in neonates to obtain a sample from the distal airway and alveolar epithelial lining fluid primarily to diagnose ongoing infectious and inflammatory process.[1,2,13–15] Though it is commonly used, the BAL technique has not been standardized in children. The only available guideline at present is "European Respiratory Society (ERS) Task Force on bronchoalveolar lavage in children".[2] The BAL procedure includes wedging of the flexible bronchoscope into a matching size bronchus and instillation of the sterile pre-warmed normal saline solution through the working channel of bronchoscope followed by immediate withdrawal of lavage fluid. In diffuse pulmonary pathology, the right middle lobe or the left lingular lobe is selected for the BAL, being the smallest lobes in respective lung they give maximum BAL fluid recovery. On the other hand, in a localized pathology, the most affected lobe identified radiologically or endoscopically should be subjected to BAL.[16] However, limited evidence is available concerning the total volume of saline and the number of aliquots needed to obtain a satisfactory BAL sample in the pediatric practice. Some bronchoscopists calculate the saline volume according to the body weights of the child as 3 ml/kg of the total amount in three equally divided aliquots until the body weight of 20 kg and three 20 ml aliquots are used in heavier children.[17,18] de Blic et al. proposed to adjust the maximum instilled saline volume up to 10% of the child's functional residual capacity, and according to them each aliquot ranges from 5-20 ml depending on the child's size.[2]There are two methods of suction to recover the instilled saline: continuous wall mounted suction and handheld syringe suction. BAL fluid should be recovered soon after the injection without any dwelling time either using continuous wall suctioning or handheld syringe suctioning. The procedure is considered as unacceptable if the fluid recovery is less than 40%.[2] When the continuous wall suctioning is used, the negative suctioning pressure should be set before the

procedure. It should be adequate to overcome the resistance of the working channel of the bronchoscope, but too much negative pressure can cause bronchial collapse and significant reduction of fluid recovery. Handheld syringe suctioning can be done directly through the working channel of the bronchoscope via the same syringe (20 ml, 30 ml, and 60 ml) had been used for instilling of saline, using gentle manual pressure. During this procedure, the pressure can be adjusted during the suctioning if visible airway collapse is noticed.

There are very few studies comparing both suction techniques, especially in children. In 2012, Rosas-Salazar et al. compared mechanical wall suctioning and manual syringe suctioning retrospectively in pediatric BAL and found higher fluid recovery (49.1 % vs 56.3%; P<0.001) and more technical acceptable BAL (74.6% vs 90.7%) with as threefold higher odds (p=0.002) in the later group.[7] Overall we had lesser BAL fluid recovery compared to study by Rosas-Salazar et al. The reason for lower recovery may be that we used bronchoscope with 1.2 mm suction channel in all patients. In contrast, in a study by Rosas-Salazar, they used bronchoscope with 2.0 mm suction channel in about 19% of patients.[7] In our study, we had opposite results; the wall mount suction was better than the syringe method. The study by Rosas-Salazar et al. was retrospective in nature, and it may introduce bias.

The BAL fluid recovery in syringe technique may be enhanced by using a plastic tube between the syringe and working channel of a flexible bronchoscope. Rosell et al., in a study in adults, reported that BAL fluid recovery was more in syringe technique with a plastic tubing compared to syringe technique without a plastic tubing (43.2% vs 35.2%, p-value <0.005) along with better diagnostic yield, fewer complications and fewer technical failure in the syringe with plastic tubing.[9] We didn't use connecting tubing, and we had slightly better recovery in syringe technique without tubing than the study by Rosell et al. (37.8 % vs 35.2 %). Singletary et al. compared two techniques (syringe with plastic tube vs syringe alone) of BAL fluid aspiration in 20 rhesus macaques and found better recovery and a higher concentration of cells in technique using plastic tubing, though there was no difference in complications and differential cell counts.[19] In another study in dogs by Woods et al., authors compared manual aspiration using syringe via a tubing and suction pump aspiration using a suction trap. They found that BAL fluid recovery, surfactant score and neutrophil count was significantly higher in the suction pump aspiration technique.[10] A RCT in 220 adults under conscious sedation compared handheld syringe with a connecting tube and wall mount suction with a trap for BAL and the recovery was more in handheld syringe technique (44.7+- 13.3 vs 36.7+- 14.7 %, p-value <0.001).[11]Another RCT in 66 adults under conscious sedation reported no difference in BAL fluid recovery between handheld syringe (no report of using connecting tubing) and wall mount technique (42 vs 40 %, p-value 0.63).[12] There was no difference in diagnostic yield between the group in both the RCTs in adults.[11,12]

BAL fluid recovery depends on many factors. There should be optimal (neither high nor low) negative suction pressure as high pressure may cause the collapse of airways and low pressure may not be sufficient for fluid recovery.[8] In children, BAL fluid recovery was reduced in younger age and BAL having a high percentage of neutrophils.[20] BAL fluid recovery is less in obstructive diseases[2], and it is more for right middle lobe and lingula compared to other lobes.[11,12] A RCT in 20 adults patients in mechanical ventilation compared BAL fluid yield by an adult (5.9 mm) and pediatric (3.4 mm) bronchoscopes and reported significantly less fluid recovery with pediatric size bronchoscope (30 % vs 40 %, p-value <0.05). However, there was no difference in diagnostic yield.[21] General anaesthesia (GA) using endotracheal intubation and mechanical ventilation in adult patients was associated with significantly lower BAL fluid recovery compared to BAL under local anaesthesia.[22] We could not find a study comparing BAL fluid recovery using GA with laryngeal mask airway (LMA) versus conscious sedation.

It will be difficult to compare the findings of our study and only available another study in children by Rosas-Salazar et al.[7] because of the many differences between both studies. In our RCT, the average age of the cohort was 2.5 years, we used same size (3.8 mm outer diameter with 1.2 mm suction channel) bronchoscope for all children, and all procedures were done under conscious sedation. The retrospective study by Rosas-Salazar et al. had an average age of 5.2 years, used larger bronchoscope with 2.0 mm suction channel in about 19% procedures, and performed procedures under LMA in about 86 % children.

Strength of our study is the randomized design in children with a variety of diagnoses and procedure performed using the same size of the bronchoscope. We had few limitations also. Firstly, we could not enrol the desired number as per calculated sample size, though it is unlikely that primary outcome might have differed, we enrol desired sample size. We calculated the sample size based on the pediatric retrospective study. If we calculate sample size based on RCT in adults[11], the sample size will be 43 in each group (total 86), and then our sample size (73) is reasonable. The study was not powered to see the yield of various investigations on BAL.

Our study and previous studies on BAL fluid aspiration technique showed inconsistent results. The aim of suction technique should be such that it should retrieve the BAL fluid, but without causing the collapse of the airways because the collapse of the airway will cause a decreased return of volume, trauma to airway, and mixing of blood with BAL fluid.[8,23] In future studies, it may be interesting to compare three techniques (wall mount suction, syringe suction with or without plastic tubing) in a large number of children with considering bronchoscope size and level of sedation (conscious sedation vs GA using LA vs GA with endotracheal intubation) to identify a better suction technique.

Conclusion

The wall-mount continuous suction is better for BAL fluid recovery in children undergoing flexible bronchoscopy under conscious sedation. Larger studies may be required to recommend a preferred BAL aspiration technique in children.

References

1. Barbato A, Magarotto M, Crivellaro M, Novello A, Cracco A, de Blic J, et al. Use of the paediatric bronchoscope, flexible and rigid, in 51 European centres. Eur Respir J. 1997;10:1761–6.

2. de Blic J, Midulla F, Barbato A, Clement A, Dab I, Eber E, et al. Bronchoalveolar lavage in children. ERS Task Force on bronchoalveolar lavage in children. European Respiratory Society. Eur Respir J. 2000;15:217–31.

3. Le Roux P, de Blic J, Albertini M, Bellon G, Body G, Bremont F, et al. [Flexible bronchoscopy in children. Experience at French centres of pediatric pneumology]. Rev Mal Respir. 2004;21:1098–106.

4. Barnett AM, Jones R, Simpson G. A Survey of Bronchoscopy Practice in Australia and New Zealand. J Bronchol Interv Pulmonol. 2016;23:22–8.

5. Honeybourne D. Survey of flexible fibreoptic bronchoscopy in the UK. Eur Respir J. 2002;20:789.

6. Leong AB, Green CG, Kurland G, Wood RE. A survey of training in pediatric flexible bronchoscopy. Pediatr Pulmonol. 2014;49:605–10.

7. Rosas-Salazar C, Walczak SA, Winger DG, Kurland G, Spahr JE. Comparison of two aspiration techniques of bronchoalveolar lavage in children. Pediatr Pulmonol. 2014;49:978–84.

8. Technical recommendations and guidelines for bronchoalveolar lavage (BAL). Report of the European Society of Pneumology Task Group. Eur Respir J. 1989;2:561–85.

9. Rosell A, Xaubet A, Agusti C, Castella J, Puzo C, Curull V, et al. A new BAL fluid instillation and aspiration technique: a multicenter randomized study. Respir Med. 2006;100:529–35.

10. Woods KS, Defarges AMN, Abrams-Ogg ACG, Dobson H, Viel L, Brisson BA, et al. Comparison between manual aspiration via polyethylene tubing and aspiration via a suction pump with a suction trap connection for performing bronchoalveolar lavage in healthy dogs. Am J Vet Res. 2013;74:523–9.

11. Seijo LM, Flandes J, Somiedo MV, Naya A, Manjon J, Alvarez S, et al. A Prospective Randomized Study Comparing Manual and Wall Suction in the Performance of Bronchoalveolar Lavage. Respiration. 2016;91:480–5.

12. Radhakrishna N, Farmer M, Steinfort DP, King P. A Comparison of Techniques for Optimal Performance of Bronchoalveolar Lavage. J Bronchol Interv Pulmonol. 2015;22:300–5.

13. Faro A, Wood RE, Schechter MS, Leong AB, Wittkugel E, Abode K, et al. Official American Thoracic Society technical standards: flexible airway endoscopy in children. Am J Respir Crit Care Med. 2015;191:1066–80.

14. Meyer KC, Raghu G, Baughman RP, Brown KK, Costabel U, du Bois RM, et al. An official American Thoracic Society clinical practice guideline: the clinical utility of bronchoalveolar lavage cellular analysis in interstitial lung disease. Am J Respir Crit Care Med. 2012;185:1004–14.

15. Perez-Frias J, Moreno Galdo A, Perez Ruiz E, Aguero BGD, Isabel M, Escribano Montaner A, et al. Pediatric Bronchoscopy Guidelines. Arch Bronconeumol Engl Ed. 2011;47:350–60.

16. Pohunek P, Pokorna H, Striz I. Comparison of cell profiles in separately evaluated fractions of bronchoalveolar lavage (BAL) fluid in children. Thorax. 1996;51:615–8.

17. Riedler J, Grigg J, Stone C, Tauro G, Robertson CF. Bronchoalveolar lavage cellularity in healthy children. Am J Respir Crit Care Med. 1995;152:163–8.

18. Grigg J, van den Borre C, Malfroot A, Pierard D, Wang D, Dab I. Bilateral fiberoptic bronchoalveolar lavage in acute unilateral lobar pneumonia. J Pediatr. 1993;122:606–8.

19. Singletary ML, Phillippi-Falkenstein KM, Scanlon E, Bohm RP, Veazey RS, Gill AF. Modification of a common BAL technique to enhance sample diagnostic value. J Am Assoc Lab Anim Sci JAALAS. 2008;47:47–51.

20. Svedberg M, Kotz K, Hesselmar B. Bronchoalveolar lavage fluid recovery in children correlates with age and neutrophils. Eur Respir J [Internet]. 2014 [cited 2020 May 28];44. Available from: https://erj.ersjournals.com/content/44/Suppl_58/4657

21. Ricou B, Grandin S, Nicod L, Thorens JB, Suter PM. Adult and paediatric size bronchoscopes for bronchoalveolar lavage in mechanically ventilated patients: yield and side effects. Thorax. 1995;50:290–3.

22. de Blasio F, Daughton DM, Thompson AB, Robbins RA, Spurzem JR, Sisson JH, et al. General vs local anesthesia. Effect on bronchoalveolar lavage findings. Chest. 1993;104:1032–7.

23. Balfour-Lynn IM, Spencer H. Bronchoscopy–how and when? Paediatr Respir Rev. 2002;3:255–64.

Figure legends

Figure 1: Flow diagram of the progress through the phases of trial

Figure 2: BAL fluid recovery (%) for handheld syringe and wall-mount suction group

Hosted file

`Table 1-3.docx` available at https://authorea.com/users/328546/articles/455778-wall-mounted-versus-handheld-syringe-suction-for-pediatric-bronchoalveolar-lavage-a-randomized-controlled-trial