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Percutaneous Pigtail Catheters for Management of Neonatal Pneumothorax: A Better Alternative to Chest Tube Thoracostomy

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Abstract

Background: Pneumothorax is potentially a life-threatening condition in neonates with little compensatory pulmonary reserve. Hemodynamically significant pneumothorax requires drainage with large-bore chest tubes, and more recently with small-calibre percutaneous pigtail catheters.

This study aims to explicate the effectiveness and safety of both the drainage systems exploring ease of insertion, rates of air-leak resolution, recurrence rates as well as potential procedural complications.

Methods: This was a retrospective observational audit reviewing medical records of newborns with symptomatic pneumothorax admitted to tertiary neonatal intensive care unit over 4-year duration, and treated with either chest tube or pigtail catheters as the initial treatment approach. Demographic data, details related to pneumothorax, drain related parameters as well as outcome and efficacy parameters were compared among these two methods of intervention.

Results: Out of 51 drainage procedures, 27 infants underwent pigtail insertion compared to 24 infants requiring chest tube thoracostomy. Baseline demographic data, time for radiological clearance and resolution of air leak, duration of drain in-situ, recurrence and complication rate, as well as hospitalisation duration were comparable among the two groups. Group of infants who underwent pigtail insertion required significantly less sedation (51.9% vs 83.3%; p=0.021) and invasive ventilation (63% vs 95.8%; p=0.011) than chest tube insertion. Significantly smaller calibre (8.22±1.6Fr vs 9.08±1.44Fr; p<0.05) catheter was required for pneumothorax drainage with pigtail catheter whose insertion was reported to be more operator friendly.

Conclusion: Pigtail catheters, in terms of efficacy and safety, are comparatively better alternatives to traditional chest tubes in the management of neonatal pneumothorax.

Keywords: Neonatal, Pneumothorax, Chest Tube, Percutaneous Pigtail Catheter, Thoracostomy

Introduction

Pneumothorax is the most common air leak caused by over distension and rupture of alveolar wall with collection of air in intra-alveolar space. It is potentially a life-threatening condition occurring more frequently in newborn period and is associated with higher morbidity and mortality rate particularly in preterm and low birth weight infants as well as increases the risk of chronic lung diseases [1,2,3,4]. Having a little compensatory reserve in newborns when air leak happens, it requires prompt diagnosis and treatment [5]. Though most of the stable pneumothoraces are managed conservatively, clinically significant ones are treated traditionally with needle thoracotomy followed by large-bore chest tube placement. In recent times, the use of modified percutaneous pigtail catheter has been suggested as a less invasive approach and there have been some studies reporting its better tolerability and safety [6,7,8].

However, enough evidence regarding the efficacy and usefulness of pigtail catheter compared to traditional chest tube drainage of pneumothorax in term and preterm neonatal population is still debatable[9]. Pigtail catheter insertion has also been purported to be safer, faster and easier to master, but its verification in the local neonatal population is still lacking.

Aims of The Study

This study aims to compare the efficacy and safety of traditional chest tubes versus modified percutaneous pigtail catheters in treating term and preterm neonates with pneumothorax at a tertiary NICU unit. This study also aims to look at the differences in the ease of insertion, outcome rates of drainage and recurrence as well as potential complications of both procedures. The study team hypothesize that percutaneous pigtail catheters would be comparatively as effective as traditional chest tubes in treating neonatal pneumothorax in the local population, regardless of operator's clinical experience level.

Material and Methods

Study Site and Population

This was a retrospective observational study that included the newborns with pneumothorax admitted to NICU of KK Women's and Children's Hospital, Singapore between January 2017 and December 2020. The study team reviewed the medical records of neonates that required either percutaneous pigtail catheter or chest tube placement as per departmental guidelines to drain clinically significant pneumothoraxes. Those who had either of the procedure performed for indications other than pneumothoraxes were excluded from our study.

Operational Design and Procedures of the Study

The diagnosis of pneumothorax was made by performing conventional chest X-ray (CXR) in symptomatic neonates. The decision regarding the need and type of drain to insert was made by the attending neonatologist consultant in charge. Medical records of 51 neonates were analysed and based on type of drain they were divided into two groups: pigtail catheter vs chest tube. Physical medical files as well as the hospital digital platform (Citrix™) containing medical records were reviewed, data collected and anonymised. Ethics committee approval was not required for our study as it was a retrospective review audit of current standard practice. Air leak drainage being an emergency procedure, verbal consent was sought from parents first followed by written consent subsequently. All procedures

were carried out according to standard departmental guidelines of our unit for either chest tube insertion (Argyle™ Trocar Catheter, USA, size 8-12 Fr) or percutaneous pigtail catheter insertion (SKATER™ Single Step Pigtail, Argon Medical Devices, USA, size 6-10 Fr). The procedure was performed by a neonatologist and/or senior pediatric residents who have received training and accredited to be proficient to perform procedure.

Thoracotomies were performed in the 4th or 5th intercostal space in the mid-axillary line [10]. For chest tube insertion, the skin and subcutaneous tissues were dissected after the application of 1-2ml of 2% lidocaine as local anaesthetic agent. A trocar needle-tube combination set was inserted until gush of air was obtained following which the tube was sutured and fixed on to the skin. In neonates receiving pigtail catheter thoracostomy, the modified Seldinger technique of insertion was used. After preparing chest wall with local anaesthesia, an introducer needle, soft-tipped J wire and catheter placed over the wire were introduced and catheter advanced over wire until air is drained. Confirmatory CXR was taken at the end of either of the procedure to check the placement position of the catheters. Post procedure, both catheters were attached to an underwater seal drainage system (Romo- Seal Kid, Romsons®, USA) with negative suction pressure of 5-10mm of Hg.

Measurement of Outcomes

From each medical record, data was collected for: (1) Neonatal demographics that included gestational age, birth weight, gender, mode of delivery, APGAR score, associated lung diseases, use of antenatal steroids and surfactant use, (2) Details related to pneumothorax occurrence including day of occurrence, location, mode of ventilation and oxygen requirements at the time of pneumothorax, (3) Intervention and catheter-related parameters like size of catheter, time to intervene, level of training of the individual and ease of performing the procedure, associated needle aspiration, adjustments required and sedation used, (4) Treatment outcomes for both groups such as complications of procedure, ventilatory and/or oxygen requirements after drain insertion, time for radiological clearance of air leak, total duration of drains, any re-accumulation and/or recurrence of pneumothorax, complications of the procedure, eventual survival as well as total hospitalization days.

The primary outcome for this study was the efficacy of the drainage (percutaneous pigtail catheter versus traditional chest tube) defined as the complete resolution of the pneumothorax after drainage confirmed by CXR. Secondary outcomes studied were the presence of any recurrence of pneumothorax, safety, ease and complications of the procedure, improvement in ventilation following drainage of the pneumothorax, mortality and duration of hospital stay.

Statistical Analysis

Statistical analysis was performed on the above data obtained from medical records on hospital computer using statistical software for Windows IBM (SPSS, Chicago, IL, USA, version 27.0). Continuous variables were described as mean ± standard deviation or as median with interquartile range (IQR; 25th – 75th centiles), and compared using Student t test. Nominal variables were analysed using the Chi-square test or Fisher's exact test according to the sample size. For all tests, p value of <0.05 was considered to be statistically significant and 95% confidence interval (CI) was calculated for statistically significant data result.

Results

Out of 46585 live births at our tertiary hospital from January 2017 and December 2020, there were 142 diagnosed cases of neonatal pneumothorax. Of these, 51 neonates required intervention and drainage of pneumothorax. Dividing analysed data into 2 groups, there were 27 infants (53%) who underwent percutaneous pigtail catheter insertion and 24 infants (47%) who had a traditional chest tube placed for the management of pneumothorax.

Demographics

The average gestational age at birth was 34.6 ± 5.2 weeks with mean birth weight of 2387 ± 962g for the pigtail catheter group as compared to 32.2 ± 5.8 weeks and 1965 ± 1108g for the chest tube group. As shown in Table 1, the demographic data of the neonates including gestation at birth, birth weight, gender, mode of delivery and APGAR score of ≤ 5 at 5 minutes of life did not differ significantly between the two study groups. There was also no statistically significant difference in both groups about use of antenatal corticosteroids, presence of meconium-stained liquor at delivery, underlying associated pulmonary diseases and postnatal surfactant use.

Variables	Pigtail Catheter (n =27)	Chest Tube (n=24)	p-Value
Gestational age in weeks; *mean ± SD*	34.6 ± 5.2	32.2 ± 5.8	0.121
Birth weight in grams; *mean ± SD*	2387 ± 962	1965 ± 1108	0.152
Gender (Male: Female); *n (%)*	16 (59.3%): 11 (40.7%)	12 (50%): 12 (50%)	0.782
Caesarean section; *n (%)*	19 (70.4%)	20 (83.3%)	0.335
Meconium-stained liquor; *n (%)*	6 (22.2%)	2 (8.3%)	0.255
Antenatal corticosteroids; *n (%)*	7 (25.9%)	11 (45.8%)	0.108
Apgar score ≤ 5 at 5 min; *n (%)*	4 (14.8%)	4 (16.7%)	0.745
Associated Lung Disease; *n (%)* RDS; *n (%)* TTNB; *n (%)* MAS; *n (%)* Others; *n (%)*	25 (92.6%) 8 (29.6%) 9 (33.3%) 1 (3.7%) 7 (25.9%)	24 (100%) 14 (58.3%) 4 (16.7%) 1 (4.2%) 5 (20.9%)	0.296 0.051 NS NS NS
Surfactant use; *n (%)*	15 (55.6%)	19 (79.2%)	0.136
MAS - Meconium Aspiratory Syndrome; NS - Not Significant; RDS - Respiratory Distress Syndrome; SD - Standard Deviation; TTNB - Transient Tachypnea of the Newborn			

Table 1: Demographic Data of Neonates requiring Pneumothorax drainage

Drainage Procedure Characteristics

Variables	Pigtail Catheter (n =27)	Chest Tube (n=24)	p-Value
Day of life at occurrence of pneumothorax; *mean ± SD* *median (IQR)*	 1.67 ± 2.15 1 (1 - 1)	 3.48 ± 4.96 2 (1 - 2)	 0.920
Location (Right: Left: Bilateral); *n*	11: 14: 2	13: 10: 1	0.607
Needle aspiration prior to intervention; *n (%)*	5 (18.5%)	6 (25.0%)	0.736
Time from diagnosis to intervention in hours; *mean ± SD*	3.2 ± 7.8	2.5 ± 4.2	0.669
Size of Catheter in Fr (6:8:10:12); n *mean ± SD*	7:10:10:0 8.22 ± 1.6	0:14:7:3 9.08 ± 1.44	0.050 (CI -1.723 to 0.0)
Sedation required during intervention; *n (%)*	14 (51.9%)	20 (83.3%)	0.021 (CI 0.16 to 0.99)
Operator level – resident: specialist; *n (%)*	16 (59.3%): 11 (40.7%)	13 (54.2%): 11 (45.8%)	0.782
Operator's reported ease of insertion (range of 1-5; from least difficult to most)	1.33 ± 0.48	2.78 ± 1.09	0.001 (CI -1.91 to -0.98)
Operator's experience in years; *mean ± SD*	8 ± 4	13 ± 8	0.015 (CI -8.6 to -0.9)
CI - Confidence Interval; IQR - Interquartile Range (25th-75th percentile); SD - Standard Deviation			

Table 2: Details relating to Pneumothorax and Chest Drain Intervention

The average day of life at point of occurrence of the air-leak and the location of the pneumothorax (left versus right versus bilateral) was similar in both groups (Table 2). 18.5% of infants from the pigtail catheter group and 25% of infants from the chest tube group underwent needle aspiration before definitive drainage was performed. It took an average of 3.2 ± 7.8 hours from time of diagnosis of the air leak to definitive drainage intervention for the pigtail group, and 2.5 ± 4.2 hours for the chest tube group and this was not statistically significant.

Notably, as shown in Table 2, a significantly (p = 0.050; CI -1.723 to 0.0) smaller calibre percutaneous pigtail catheter insertion (8.22 ± 1.6Fr) was used for pneumothorax drainage as compared to the size of traditional chest tube (9.08 ± 1.44Fr). Less sedation was required in infants who underwent pigtail catheter insertion compared to those who had traditional chest tubes placed (51.9% versus 83.3%; p = 0.021; CI 0.16 to 0.99) for the drainage.

From an operator point-of-view, percutaneous pigtail catheters were reported to be easier to insert compared to that of traditional chest tube (range of 1-5 from least difficult to most; 1.33 ± 0.48 versus 2.78 ± 1.09) and this was noted to be statistically significant (p = 0.001; CI -1.91 to -0.98). In addition, there was also a significant difference (p = 0.015; CI -8.6 to -0.9) in the operator's post-graduate level of experience between both groups (in years; 8 ± 4 years for pigtail group versus 13 ± 8 years for chest tube group).

Outcomes

As revealed from Table 3, post intervention, a significantly smaller number of infants required invasive ventilation after drainage had been performed in pigtail catheter group (n=17/27, 63% vs n=23/24, 95.8%; p = 0.011; CI -0.61 to -0.04) compared to chest tube infants group. Pre and post procedure maximum Fraction of Inspired Oxygen (FiO2) requirement and the reductions in FiO2

Variables	Pigtail Catheter (n =27)	Chest Tube (n=24)	p-Value
Ventilation mode (non-invasive: invasive) Prior to intervention; n (%) Post-intervention; n (%)	 11 (40.7%): 16 (59.3%) 10 (37.0%):17 (63.0%)	 5 (20.8%): 19 (79.2%) 1 (4.2%):23 (95.8%)	 0.113 0.011 (CI -0.61 to -0.04)
Maximum FiO2 requirement Prior to intervention; mean ± SD median (IQR) Post-intervention; mean ± SD median (IQR)	 50 ± 30 35 (30 - 100) 44 ± 31 30 (20 - 75)	 64 ± 32 62 (33 - 100) 55 ± 31 40 (29 - 100)	 0.141 0.248
Reduction in FiO2 requirement post-intervention; mean ± SD	6 ± 7	9 ± 25	0.570
Drain adjustment post-intervention; n (%)	8 (29.6%)	4 (16.7%)	0.335
Time for radiological clearance in hours;mean ± SD median (IQR)	17 ± 32 1.5 (0 - 31.5)	33 ± 43 7 (1 - 62)	0.185
Total duration of drain in days; mean ± SD median (IQR)	3.7 ± 4 2 (2 - 4)	3.6 ± 2 3 (2 - 5)	0.961
Total duration of hospitalisation in days;mean ± SD median (IQR)	30 ± 53 8 (4 - 30)	67 ± 80 22 (8 - 134)	0.050 (CI -74.8 to -0.98)
Total duration of hospitalisation in days (excluding deaths); mean ± SD median (IQR)	 33 ± 58 9 (6 - 26)	 75 ± 85 29 (8 - 162)	 0.063
Survival; n (%)	22 (81.5%)	20 (83.3%)	1.000
CI - Confidence Interval; FiO2 - Fraction of Inspired Oxygen (in percentage); IQR - Interquartile Range (25th-75th percentile); SD - Standard Deviation			

Table 3: Primary and Secondary Outcomes of Chest Drain Interventions

requirements post intervention were analytically comparable for both groups. Post procedure, no major complications occurred in neonates of our study groups. One infant experienced bloodstained fluid drainage after a traditional chest tube insertion which required the drainage tube to be removed and reinserted. About 20-30% of the drains inserted in both groups required post-procedure position adjustments to secure the ideal catheter tip position on CXR for optimal drainage of air from pleural space.

The time for complete radiological clearance of air-leak after drain insertion was statistically similar for both groups of infants. At our centre, the chest drain is routinely clamped and CXR is performed prior to removal of both types of chest drain. Re-accumulation of the pneumothorax was noted in 3 infants (2 from the pigtail group and 1 from the chest tube group) after the drain was clamped. However, the pneumothorax did not persist after the drain was unclamped and this had minimal impact on the total duration for which the drain was left in situ, which was comparable for both groups of infants (3.7 ± 4 days for pigtail group vs 3.6 ± 2 days for chest tube group). Re-accumulation of pneumothorax after drain removal was seen in 3 infants in the chest tube group – 2 of them required repeat drainage subsequently whereas the air leak in third one resolved spontaneously. There was no re- accumulation of pneumothorax post percutaneous pigtail catheter removal.

The total duration of hospitalisation stay was significantly lower in infants who had a percutaneous catheter inserted versus those who had chest tubes (30 ± 53 days' vs 67 ± 80 days; p = 0.050; CI -74.8 to -0.98). However, on Mann-Whitney U test regression analysis and excluding babies who died, the total number of hospitalization days does not differ between both groups. Survival rates for both groups were comparable at 81.5% (n = 22/27) for neonates who underwent pigtail catheter drainage and 83.3% (n = 20/24) for neonates who had traditional chest tubes inserted.

Discussion

Pneumothorax, the most common air leak syndrome, occurs more frequently in the neonatal period than at any other time of life, carrying a higher mortality risk in preterm neonates[11,12]. The incidence of pneumothorax varies widely worldwide and depends on various factors such as prematurity, need for respiratory support, associated respiratory condition of the newborn child and/or any concomitant lung pathologies [3,13,14]. At our institution, the incidence of symptomatic pneumothorax was 0.3% among the live-born infants which was comparable with Danish study presented by Vibede et al. in 2017[15]. About 1/3rd of symptomatic pneumothorax neonates needed chest tube drainage at our NICU (51/142).

In our study, though the attending neonatologist decided the type of chest drain intervention based on his clinical expertise as well as respiratory status of the child, there was no major difference in the basic demographics among the study groups of pigtail catheter and chest tube.

For many years, the traditional treatment of choice for drainage of pneumothorax in newborn infants is chest tube insertion until recently when there is enough promising evidence in literature towards safe routine use of pigtail catheters. Lawless et al. were one of the first who described a high success rate in the use of pigtail catheter in the treatment of pneumothorax in neonates and young children[16]. This was later further studied, reported and supplemented by scholarly work from Wood and Dubrik et al., Yi Hsuan et al. and Raffaella et al.[8.,9,17]. In our present study, there were no significant differences observed in time to radiological clearance of the pneumothorax and/or total duration of thoracotomy tube in situ for both groups of patients. Length of hospitalisation stay excluding deaths and survival rates among neonates were also similar in both groups. This observation in our study shows that pigtail catheters are a safe and effective alternative to chest tube drainage for the treatment of symptomatic pneumothorax in the neonate including very premature ones.

There were no significant complications like recurrence of pneumothorax, kinking, blockage or dislodgement of catheters, organ injuries etc. observed with the use of pigtail catheter, which is similar to observation by Wood and Dubrik and others[17,18,19,20]. In our study, one neonate who underwent chest tube insertion had an incidence of hemothorax requiring removal and reinsertion

of the drain. This could be due to the fact that chest tubes insertion procedures are more invasive and complex, requiring skin incision and dissection prior to trocar insertion, contrary to that of pigtail catheter insertion where only an introducer needle is required to enter the pleural cavity.

One proposed advantage of pigtail catheter insertion over that of traditional chest tubes is that of a smaller size and smaller incision, thus by extension leading to less trauma and better patient comfort. This has been observed and described in adults and children but more evidence is required in the neonatal population[6,21,22,23,24]. In our study, it is observed that the size of pigtail catheters used to achieve successful drainage was comparatively smaller than that required in chest tubes. The neonate have supple chest wall, their thoracic cavity and lung tissue is more fragile, and hence, a smaller catheter to potentially minimise trauma is always recommended. Given that suturing of the pigtail catheter to the chest wall is not required, this can also reduce incidence of scarring for delicate neonates after removal of the drain[25].

Our audit analysis reveals that those neonates who underwent pigtail catheter insertion required a statistically significant reduced need for systemic sedation compared to those who underwent traditional chest tube insertion. To the best of our knowledge, ours' is the first study to report this finding with regards to thoracotomy for neonatal pneumothorax. Sedation has been known to increase the additional risk of respiratory depression in already depressed neonate with air leak and thus in turn the increased risk of need for invasive ventilation. This reduction in need for sedation could partly explain the significant lesser need of invasive ventilation in the pigtail catheter group (63% vs 96%). Commonly used sedation agents like benzodiazepines and opioids when given to a neonate, especially if preterm, has the potential to cause acute complications such as hypotension and intraventricular haemorrhage, as well as chronic adverse neurological impacts[26,27]. Hence, any potential reduction in their exposure is always welcomed by concerned neonatologists.

Ease of placement of the pigtail catheter has been briefly discussed in previous studies [6,16]. Yi Hsuan et al. also reported that the procedure time required for pigtail catheter insertion was significantly shorter than that for chest tube insertion, which indirectly hints at simpler placement techniques with the pigtail catheter[9]. In addition, Wood and Dubrik have also commented that the technique for pigtail catheter placement can be easily acquired by residents in training[17]. From our current study, it was noted that there was a significant difference in operator's post-graduate level of experience between both groups, with a successful pigtail catheter insertion being achieved by an operator with less experience. In addition, when reviewing the subjective input from the operator point-of-view, percutaneous pigtail catheters were reported to be easier to insert compared to that of traditional chest tube. This can potentially have a large impact on future pneumothorax drainage practice given that a larger group of qualified individuals would be able to respond and intervene in the event of a pneumothorax emergency, and with more confidence, which could make a significant impact on post-pneumothorax neonatal morbidities outcome.

There were several limitations to our study. This was a retrospective audit, allocation of patients to chest tube versus pigtail catheter insertion was not randomised, and it was largely based on the attending consultant neonatologist's expertise and discretion limiting study selection bias. The sample size of this study is small with diverse neonatal population in terms of gestational age and birth weight. Developments in ventilatory techniques, prevalent use of antenatal steroids and postnatal surfactant administration have reduced the overall incidence and need for intervention for pneumothorax in neonates[28]. Our study lacks the long-term follow up of the survived patients and thus unable to evaluate the impact of type of procedure on long-term morbidities. Besides incidence and management of pneumothorax, there can be many confounding factors leading to overall survival and number of hospitalization days in neonates.

Conclusion

In conclusion, pigtail catheters achieved similar success in neonatal pneumothorax drainage but with usage of smaller sized catheters, need of less sedation, reduced invasive ventilatory requirements and with no additional complication rates compared to chest tubes. This suggests that pigtail catheters are effective, reliable, uncomplicated and perhaps less traumatic alternative in the management of pneumothorax compared to traditional chest tubes in vulnerable neonatal population receiving treatment for pneumothoraces in NICU. To the best of our knowledge, this study is also the first to look into operator experience and operator reported ease of drainage with regards to pneumothorax drainage in neonates, with initial results indicating that pigtail catheter is easier to master. Additional prospective studies, ideally large-scale, multicentre randomised controlled trials are required to compare and confirm better efficacy of flexible pigtail catheters over traditional wide-bore stiff chest tubes. In a nutshell, results of our analysis suggests for consideration of pigtail catheters as the initial treatment of choice for neonates with pneumothorax, and even safe to be used in very low birth weight premature infants.

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Statements

Ethical Approval

Ethical approval was not necessary, as this was a retrospective review for evaluation and audit of current standard practice. This article does not involve any trials (with neither human participants nor animals).

Informed Consent

The NICU informed consent signed by parents at hospital admission allows for the use of anonymised personal data for research and publication.

Conflict of Interest

The authors have neither conflict of interest relevant to this article nor any financial relationship with the manufacturer of any of the devices or computer programmes.

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None

Data Availability

The data pertaining to above study is available on secured work computer of the authors and will be kept stored for next 2 years. If required, we can provide data to editors and reviewers, following our departmental and hospital guidelines.

Author's Contributions

MSSMG and SJV conceptualised the study, collected data, performed statistical analysis and data interpretation; drafted, reviewed and revised the manuscript. Both authors take full responsibility for the accuracy and integrity of the study and approve the final manuscript submission.

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