DOI: https://doi.org/10.54393/pjhs.v3i06.276

PAKISTAN JOURNAL OF HEALTH SCIENCES

https://thejas.com.pk/index.php/pjhs

Volume 3, Issue 6 (November 2022)

Original Article

Management of Patients with Prolonged Air Leak after Pulmonary Resection with Heimlich Valve

Nazish Sikander[1*], Tanveer Ahmad[1], Misauq Mazcuri[1], Rafia Zafar[1] and Shifa Naz[1]

[1]Department of Thoracic Surgery, Jinnah Postgraduate Medical Centre, Karachi, Pakistan

ARTICLE INFO

Key Words:

Prolonged air leak, pulmonary resection, Heimlich valve, lobectomy, wedge resection

How to Cite:

Sikander, N., Ahmad, T. ., Mazcuri, M., Zafar, R. ., & Naz, S. . (2022). Management of Patients with Prolonged Air Leak after Pulmonary Resection with Heimlich Valve: Prolonged Air Leak after Pulmonary Resection with Heimlich Valve. Pakistan Journal of Health Sciences, 3(06). https://doi.org/10.54393/pjhs.v3i06.276

***Corresponding Author:**

Nazish Sikander

Department of Thoracic Surgery, Jinnah Postgraduate Medical Centre, Karachi, Pakistan

nazish.gaziani90@gmail.com

Received Date: 25th October, 2022

Acceptance Date: 15th November, 2022

Published Date: 30th November, 2022

ABSTRACT

Prolonged air leak (PAL) after pulmonary resection is defined as air leak persisting for five or more days. Majority can be managed conservatively using one-way device Heimlich valve (HV) while few may require surgical intervention. **Objective:** To evaluate safe discharge policy for Prolonged air leak and role of Heimlich valve in its management. **Methods:** A retrospective study was conducted in the Department of Thoracic surgery at Jinnah Postgraduate Medical Center, Karachi, including patients with PAL following pulmonary resection between the years 2019-2021. Cerfolio Grade IV air leaks were excluded. **Results:** File records of 467 patients were reviewed; seventy (15%) had PAL. Most common indication for resection was bronchiectasis (n=24; 34.3%); Lobectomy was the most common procedure (31/70; 44.3%) associated with PAL. Grade II (n=38) air leak was most commonly encountered. All grade III patients developed complications (p=0.02), followed by grade II (p=0.07) whereas Grade I had least complications (8/19; p<0.001). Lobectomy patients showed improvement of air leak on HV (p=0.008). Grade I PAL (n=19) discharged on HV had the least frequency of lung collapse (LC) and residual space (RS) (n=8; p=0.006 and n=1; p<0.001) respectively, whereas Grade III (n=13) discharged with HV developed significant number of complications; LC (n=12;92.8%; p=0.03) and RS (n=11; 84.6%; p<0.001). **Conclusions:** PAL is an important factor complicating resections. Effective preoperative preparation and meticulous resection technique can decrease complications. Nonetheless, not all patients can be discharged on HV. Patients with smaller leaks can be safely sent home on HV whereas larger leaks require management in hospital with some form of intervention.

INTRODUCTION

An air leak is defined as an egress of air from a break in pulmonary parenchyma or bronchial stump into the pleural space, evident by bubbling in the chest bottle [1]. Air leaks are the most frequently encountered complication after thoracic surgery, particularly pulmonary resection. [2, 3] If an air leak persists for more than five days, it is termed as Prolonged Air leak (PAL) [4]. In our study incidence of PAL after pulmonary resection was found to be 15%, however few studies quote up to 20-33% [5,6]. Various etiological factors have been identified for PAL after pulmonary resection including trauma due to lung manipulation, barotraumas, fissure dissection, underlying lung disease, infection and surgical technique [5]. Furthermore, certain factors increase the likelihood of PAL notably advanced age, reduced body mass index, chronic steroid use, chronic obstructive pulmonary disease (COPD), diabetes mellitus, smoking, reduced pulmonary function, and adhesions [2,7]. Regardless of the cause, PAL has a strong impact on patient morbidity resulting in protracted hospital course, frequent complications, Intensive care admission, pneumonia, empyema, atelectasis and reintervention [2,7,8]. Management strategies vary from conservative to surgical intervention with no definite consensus [2,5]. These are prolonged drainage with underwater seal, pleuravac®, physiotherapy, chemical pleurodesis, fibrin patches, use of endobronchial valves, operative intervention or discharging patients home with Heimlich valve (HV) [5,9]. HV is a one-way valve device which maintains negative intra pleural pressure, promotes removal of excess air from pleural space, helps with lung

DOI: https://doi.org/10.54393/pjhs.v3i06.276

expansion and is superior to underwater seal alone [10]. This study aims to evaluate the optimum and safe discharge policy in patients with PAL and the role of HV in its management.

METHODS

A retrospective cross-sectional study was carried out in the Department of Thoracic surgery, Jinnah Postgraduate Medical Center, Karachi from January 2019 to December 2021. It included patients with PAL following pulmonary resection. Ethical approval was attained from Institutional review board committee. PAL was defined as air leak that can be witnessed clinically for five days or more following pulmonary resection [4,11]. All patients presenting with benign or malignant parenchymal disease that required any form of pulmonary resection were included. Grade IV air leaks according to Cerfolio classification were excluded from this study [12]. Pulmonary resection performed included lobectomy, wedge and segmentectomy. All patients undergoing lobectomy had incomplete fissures. Both hand sewn and stapler technique were employed as no significant difference between the two in terms of air leak duration is found in literature [13]. All data that was documented prospectively was collected by three researchers retrospectively, through medical records whereas a separate researchers reviewed the variables. Data variables included age, gender, co-morbid, etiology, procedure type, grade of air leak according to Cerfolio classification, duration of air leak, day of application of Heimlich valve®, duration of tube or valve, complications pertaining to Heimlich valve®, need of re intervention or procedure. Common outcomes of patients influenced the development of research question. SPSS version 22 was utilized for data entry and analysis. Mean and standard deviation was utilized to represent descriptive data such as age, weight, duration of air leak or chest tube, etc. Categorical variables such as gender, disease, etiology, type of resection and others were presented as frequencies and percentages. Independent sample t test was applied for comparison of means; for categorical variables Chi square was utilized. P value ≤0.05 was taken as statistically significant.

RESULTS

In this study, 467 patient records were reviewed, out of which 70 had PAL secondary to pulmonary resection. Thirty-seven (52.9%) were females and 33(47.1%) were males. The mean age and weight of patients were 45.7 ± 11.1 years and 49.4 ± 7.9 Kgs, respectively. Diabetes (n=35; 50%) was the most common co morbidity followed by COPD (n=32; 45.7%), tuberculosis history (n=25; 35.7%) and chronic steroid use (n=16; 22.9%). Patients' addictions included smoking (32; 45.7%), Betel (30; 42.9%) and Gutka (18; 25.7%). Most common presenting complaint was hemoptysis (24; 34.3%), productive sputum (19; 27.1%), chest pain (12; 17.1%), dyspnea (8; 11.4%) and fever (7; 10%). Bronchiectasis (24; 34.3%) was the most common etiology and lobectomy (n=31; 44.3%) was the most common procedure performed. (Table 1)

	Etiology /Disease	Number (Percentage)
1	Bronchiectasis	24 (34.3%)
2	Aspergilloma	15 (21.4%)
3	Solitary pulmonary nodule	10 (14.3%)
4	Hydatid cyst	9 (12.9%)
5	Bulla	4 (5.7%)
6	Granuloma of lung	4 (5.7%)
7	Interstitial lung disease	2 (2.9%)
8	Lung carcinoma	2 (2.9%).
	Procedures	
1	Lobectomy	31 (44.3%)
2	Wedge resection	29 (41.4%)
3	Segmentectomy	10 (14.3%)

Table 1: Etiology and types of procedure performed

Upper lobe (UL) involvement was found in 39 (55.7%), lower lobe (LL) in 23 (32.9%) and middle lobe (ML) in 11 (15.7%). All hydatid cysts were seen in LL (n=9/9; p<0.001) and 3 out of 4 granuloma cases in UL (75%; p<0.001). Bronchiectasis was seen involving UL and LL (n=8;33.3% and 7;29.1%, respectively) with both cases of interstitial lung disease (ILD) in LL (p=0.04) (Table 2).

	Disease(n)	Procedure	Number/ number of Disease (%)	P value
1	Bronchiectasis	Lobectomy	21/24 (87.5%)	<0.001*
		Wedge resection	3/24(12.5%)	<0.001*
2	Aspergilloma	Wedge resection	8/15 (53.3%)	0.12
		Lobectomy	4/15(26.6%)	0.29
		Segmentectomy	3/15(20%)	0.47
3	Solitary pulmonary nodule	Wedge resection	10/10(100%)	<0.001*
4	Hydatid disease	Segmentectomy	5/9 (55.5%)	<0.001*
		Lobectomy	2/9(22.2%)	0.15
		Wedge resection	2/9(22.2%)	0.21
5	Granuloma	Wedge resection	3/4(75%)	0.16
		Lobectomy	1/4(25%)	0.42
6	Interstitial lung disease	Wedge resection	2/2(100%)	0.08
7	Bulla	Segmentectomy	2/4(50%)	0.03*
		Wedge resection	1/4(25%)	0.49
		Lobectomy	1/4(25%)	0.42
8	Carcinoma of lung	Lobectomy	2/2(100%)	0.18

*Significant

Table 2: Relation of procedure with disease.

Most common grade of air leak encountered was grade II (38; 54.2%), followed by grade I (19; 27.1%) and grade III (13; 18.6%). Post-operative lung expansion was seen in 27 (38.6%) with Grade III patients showing no immediate post-operative lung expansion (0/13; p=0.002), whereas 14 out of 19(73.6%) patients with grade I leak showed complete lung

DOI: https://doi.org/10.54393/pjhs.v3i06.276

expansion (p<0.001). Adhesions were seen in 64(91.4%) associated with 35(54.68%) developing Grade II air leak. HV was attached by 5.6 ± 0.88 day. In majority of Lobectomy and wedge resections HV was applied by day 6(p=0.01 and 0.009), however in carcinoma of lung undergoing lobectomy HV was attached by day 7(p=0.001). Mean duration of chest tube from surgery and days of air leak were 18.1 ± 4.9 days (8-27) and 13.4 ± 4.1 day (5-19), respectively.

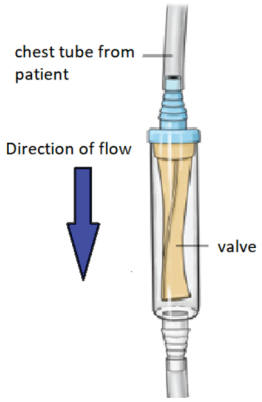

Figure 1: Pictorial presentation of Heimlich valve.

Complications were found in 53 (75.7%) patients who were discharged with HV (Figure 2). All patients with grade III developed complications (13/13; 100%; p=0.02), followed by 32 out of 38 grade II air leak patients having complications (p=0.07). Grade I patients had the lowest complications (8/19; p<0.001). Table 3 represents relation of grade of air leak and complications. Out of 29 patient undergoing wedge resection 27 (93.1%; p=0.004) developed complications whereas 17 out of 31 (32.07%; p<0.001) lobectomy patients developed complications; valve fluid accumulation was seen in 6/31 (19.3%; 0.02) followed by residual space (RS) in 4/31 (12.1%; p=<0.001). Lobectomy patients showed improvement of air leak by at least one grade with HV in 20/31(64.5%, p=0.008) and complete resolution of leak in 21/31(67.7%; p=0.002). Segmentectomy was significantly associated with RS (9/10; p<0.001). Re-admission was required in 43(61.4%) patients with lowest rate in grade I (5; 26.3%; p=0.001). Re-intervention was required in 34 (48.6%) patients; chest tube in 5(7.1%) patients, tube with suction in 21 (30%) patients, decortications in 5 (7.1%), and completion lobectomy in 3 (4.3%). Grade I had the lowest re-intervention rate (4/19; 21%; p=0.005) whereas 19/38 (50%; p=0.79) with Grade II and 11/13(84.6%; p=0.04) Grade III patients required re-intervention. Complete resolution of leak in bronchiectasis patients discharged on HV was seen in first week in 9(p=0.01) and by second week in 12 (p<0.001). Hence 21 out of 24 (87.5%) patients with bronchiectasis showed complete air leak resolution (p=0.002).

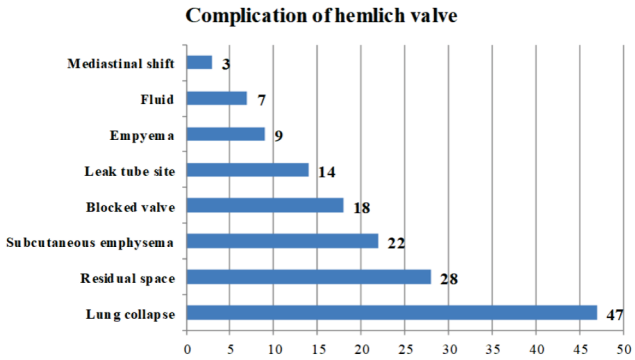

Figure 2: Complications seen in patient discharged with HV

Grade of air leak	Complication	Number/Percentage	P value
Grade I n = 19	Lung collapse	08; 42%	0.006*
	Residual space	01; 5.2%	<0.001*
	Empyema	01; 5.2%	0.24
	Readmission	05; 26.3%	0.001*
Grade II n = 38	Lung collapse	27; 71.05%	0.44
	Residual space	16; 42.1%	0.44
	Empyema	06; 15.7%	0.42
	Readmission	25; 65.7%	0.44
Grade III n = 13	Lung collapse	12; 92.3%	0.03*
	Residual space	11; 84.6%	<0.001*
	Empyema	02; 15.3%	0.7
	Readmission	13; 100%	0.007*

*Significant

Table 3: Relation of grade of air leak and complications.

Duration of PAL and HV contributed as an important factor in complications. Bronchiectasis, Solitary pulmonary nodule (SPN) and carcinoma of lung had PAL for < 2 weeks (16/24; p=0.001, 6/10; p=0.03 and 2/2; p<0.001, respectively). In aspergilloma patients 12 (80%; p<0.001) had PAL for > 2 weeks. Table 4 represents various factors and their association with PAL and HV attached for >2weeks.

	Factors	No. of cases (%)	P value
DURATION OF AIR LEAK >2 WEEKS			
1	Complications	34/53(64.1%)	<0.001*
2	Lung collapse	33/47(70.2%)	<0.001*
3	Residual space	19/28(67.8%)	0.02*
4	Fluid	4/7(57.1%)	0.006*
5	Mediastinal shift	2/3(75%)	0.003*
6	Block valve	10/18(55.5%)	0.02*
7	Re-intervention	26/34(76.4%)	0.001*
8	New tube placement	3/5(60%)	0.001*
DURATION OF HEIMLICH VALVE > 2WEEKS			
1	Complication	46/53(86.7)	<0.001*
2	Lung collapse	43/47(91.4%)	0.001*
3	Leak tube site	10/14(71.4%)	<0.001*
4	Residual space	25/28(89.2%)	0.008*
5	Block valve	16/18(88.8%)	0.05
6	Empyema	9/9(100%)	0.005*

*Significant

Table 4: Duration of air leak and HV

DOI: https://doi.org/10.54393/pjhs.v3i06.276

Patients were discharged with different sizes of chest tube, 14 out of 46(30.4; p=0.003) patients with 32 Fr. tube had tube site leak (TSL). None of the patients with 28 Fr. tube (p=0.003) had TSL, however, they had RS formation in 14/24(58.3%; p=0.02) cases. Average stay was 7.4 ± 1.15 days with no mortality.

DISCUSSION

Our review included 70 patients with PAL following pulmonary resection. Bronchiectasis (34.3%) was the leading etiology followed by aspergilloma of lung (21.4%). In literature, PAL incidence after resection was found to be between 8-26% however it varies according to the type of resection; segmentectomy (10-15%), lobectomy (9-13%) and wedge resection (3.3%) [14]. We found PAL incidence of 15% with similar or slightly higher incidence for the different types of resections. Our incidence of PAL with lobectomy was 16% (31/191) as it involved completion of the fissure. Another study also supported higher association of lobectomy with PAL as it involves resection of more pulmonary parenchyma as compared to lesser resections, gravitational effects and a larger residual space [11]. Factors such as COPD and smoking are associated with fragile lung parenchyma causing tobacco induced lung damage, thus lead to reduced healing capacity and PAL [6]. Furthermore, tuberculosis history is strongly correlated with lung scarring and impaired gas exchange ultimately leading to PAL [15]. In our study, diabetes was found in 35 (50%), COPD in 32 (45.7%), tuberculosis history in 25 (35.7%) and 32 (45.7%) patients were smokers. Previous studies have shown adhesions to be an important risk factor for PAL due to parenchymal tears during mobilization of lung [11]. We found adhesions in 64(91.4%) associated with 35(54.68%) developing Grade II air leak. Treatment modalities for PAL range from conservative techniques such as application of Heimlich valve (HV), implantable devices notably tissue adhesives and endobronchial valves, chemical pleurodesis to surgical intervention [15, 16]. PAL increases the length of hospital stay and impacts additional cost on healthcare system [15]. Castillo et al. described PAL as the second most common cause of prolonged hospitalization post-lobectomy [15]. In our study, average length of hospital stay was 7.4 ± 1.15 days which was similar to 7.9 days found in another study [4]. HV has shown to be effective for PAL by allowing the lung to heal, residual lung to expand, reduce nosocomial infections, allow patient mobility and manage patients in an outpatient setting [17,18]. HV has proved to be beneficial in lobectomy cases resulting in resolution of PAL [19]. Same was seen in our study, where HV in lobectomy cases with PAL showed improvement of grade of air leak (64.5%, p=0.008) and its resolution in 67.7% cases (p=0.002). Nonetheless, there are certain complications of HV. J. Matthew reported empyema in 16.9% patients when discharged home on HV requiring reoperations in 22.9% [7]. In our review, empyema occurred in 12.9% patients. Most complications were seen in patients undergoing wedge resection (p=0.004) followed by lobectomy (p<0.001) and segmentectomy (p<0.001). Reoperation was mandated in 11.4%, while 37.1% were managed by reinsertion of chest tube attached to suction. The overall readmission rate in our study was 61.4% which is higher than what was observed in previous studies (19.4-26.3%) [4,7]. Aggressive early discharge for PAL with HV attributes to shorten hospitalization and cost benefits but it is not without consequence [7]. Our primary goal was to establish which grade of PAL can be safely discharged on HV. This study demonstrates that Grade I PAL can be safely discharged home on HV as it has the least frequency of lung collapse (LC) and residual space (RS) (8/19; p<0.006 and 1/19; p<0.001), respectively. Patients with Grade II PAL do not show significant values whereas Grade III PAL when discharged with HV developed significant complications; LC (92.3%; p<0.03) and RS (84.6%; p<0.001). Duration of air leak> 2 weeks was statistically consistent with complications (p<0.001), of which most common was LC (33/47; p<0.001). Moreover, prolonged use of HV can lead to dysfunction of valve mechanism due to disruption of rubber leading to complications such as tube site leakage, blocked valve, empyema and lung collapse [17]. This was consistent with our findings; prolonged use of HV> 2weeks led to complications (p<0.001) notably LC (91.4%; p<0.001), RS (89.2%; p<0.008) and tube site leak (71.4%; p<0.001). Patients with bronchiectasis can be safely discharged on HV as complete resolution of PAL was witnessed (p=0.002) when duration of leak did not exceed two weeks (p=0.001). On the other hand, 80% patients with aspergilloma had PAL for more than 2 weeks (p<0.001) and should not be discharged on HV. Considering available data, patients with PAL can be safely discharged with a portable device by Day 4-8 depending on the underlying etiology, procedure performed and grade of air leak [3,20]. However, we attached HV by 5.6 ± 0.88 day and observed for few days before sending home. Our study has certain limitations: It is a single centre, retrospective study with small sample size. However, it does lay grounds for future prospective research on this subject.

CONCLUSIONS

PAL after lung resection is a vexing problem faced by thoracic surgeons that increases hospitalization. It can be concluded by our study that patients can be safely sent home on Heimlich valve for Grade I PAL. However, patients with Grade III PAL are more likely to develop complications so they are better to be managed in hospital. A more strategic plan focusing on optimizing preoperative risk

DOI: https://doi.org/10.54393/pjhs.v3i06.276

factors, meticulous intraoperative technique and optimum postoperative management can result in improved outcomes and readmission.

Conflicts of Interest

The authors declare no conflict of interest

Source of Funding

The author(s) received no financial support for the research, authorship and/or publication of this article

REFERENCES

[1] Elsayed H, McShane J, Shackcloth M. Air leaks following pulmonary resection for lung cancer: is it a patient or surgeon related problem? Annals of The Royal College of Surgeons of England. 2012 Sep; 94(6):422-427. doi: 10.1308/003588412x13171221592258

[2] Dugan K, Laxmanan B, Murgu S, Hogarth D. Management of Persistent Air Leaks. Chest. 2017 Aug; 152(2):417-423. doi: 10.1016/j.chest.2017.02.020

[3] French D, Plourde M, Henteleff H, Mujoomdar A, Bethune D. Optimal management of postoperative parenchymal air leaks. Journal of Thoracic Disease. 2018 Nov; 10(S32):S3789-S3798.doi:10.21037/jtd.2018.10.05

[4] Minervini F, Hanna W, Brunelli A, Farrokhyar F, Miyazaki T, Bertolaccini L, *et al*. Outcomes of patients discharged home with a chest tube after lung resection: a multicentre cohort study. Canadian Journal of Surgery. 2022 Feb; 65(1):E97-E103. doi: 10.1503/cjs.006420

[5] Bronstein M, Koo D, Weigel T. Management of air leaks post-surgical lung resection. Annals of Translational Medicine. 2019 Aug; 7(15):361-361. doi: 10.21037/atm.2019.04.30

[6] Zheng Q, Ge L, Zhou J, Zhang Y, Lyu M, Chen C, *et al*. Risk factors for prolonged air leak after pulmonary surgery: A systematic review and meta-analysis. Asian Journal of Surgery. 2022 Feb; 45(11):2159-2167. doi: 10.1016/j.asjsur.2022.01.001

[7] Reinersman J, Allen M, Blackmon S, Cassivi S, Nichols F, Wigle D, *et al*. Analysis of Patients Discharged from the Hospital with a Chest Tube in Place. The Annals of Thoracic Surgery. 2018 Apr; 105(4):1038-1043. doi: 10.1016/j.athoracsur.2017.10.042

[8] Attaar A, Luketich JD, Schuchert MJ, Winger DG, Sarkaria IS, Nason KS. Prolonged Air Leak After Pulmonary Resection Increases Risk of Noncardiac Complications, Readmission, and Delayed Hospital Discharge: A Propensity Score-adjusted Analysis. Annals of Surgery. 2021 Jan; 273(1):163-172. doi: 10.1097/SLA.0000000000003191.

[9] Korasidis S, Andreetti C, D'Andrilli A, Ibrahim M, Ciccone A, Poggi C, *et al*. Management of residual pleural space and air leaks after major pulmonary resection. Interactive Cardio-Vascular and Thoracic Surgery. 2010 Jun; 10(6):923-925. doi: 10.1510/icvts.2009.231241

[10] Bar I, Papiashvilli M, Kurtzer B, Bahar M. Effect of Heimlich valve and underwater seal on lung expansion after pulmonary resection. Indian Journal of Thoracic and Cardiovascular Surgery. 2009 Dec; 25(4):183-187. doi: 10.1007/s12055-009-0053-5

[11] Drewbrook C, Das S, Mousadoust D, Mousadoust D, Mousadoust D, Nasir B, *et al*. Incidence Risk and Independent Predictors of Prolonged Air Leak in 269 Consecutive Pulmonary Resection Patients over Nine Months: A Single-Center Retrospective Cohort Study. Open Journal of Thoracic Surgery. 2016 Nov; 6(4):33-46. doi: 10.4236/ojts.2016.64006

[12] Cerfolio RJ. Advances in thoracostomy tube management. Surgical Clinics. 2002 Aug; 82(4):833–48. doi: 10.1016/s0039-6109(02)00026-9

[13] Tantraworasin A, Seateang S, Bunchungmongkol N. Staplers versus hand-sewing for pulmonary lobectomy: randomized controlled trial. Asian Cardiovascular and Thoracic Annals. 2013 Mar; 22(3):309-314. doi: 10.1177/0218492313491754

[14] Yoo A, Ghosh S, Danker III W, Kassis E, Kalsekar I. Burden of air leak complications in thoracic surgery estimated using a national hospital billing database. Clinico Economics and Outcomes Research. 2017 Jun; 9:373-383. doi: 10.2147/ceor.s133830

[15] Castillo-Acosta S, Castillo-Acosta J, Rodríguez-Suárez P, González-Martín J, Freixinet-Gilart J. Outpatient management of persistent air leak. Archivos de Bronconeumología. 2021 Nov; 57(11):722-723. doi: 10.1016/j.arbr.2021.09.011

[16] Kurman JS. Persistent air leak management in critically ill patients. Journal of Thoracic Disease. 2021 Aug; 13(8):5223. doi: 10.21037/jtd-2021-32

[17] Aini, F. and Syafa'ah, I. Heimlich Valve as an Ambulation Management of Persistent Pneumothorax or Fluidopneumothorax. Jurnal Respirasi. 2021 May; 7(2):86. doi: 10.20473/jr.v7-i.2.2021.86-92

[18] Alaydi J, Qayet A, Haddadin M, Kaisy K, Alhadidi H. Heimlich Valve for the Management of Post Operative Air Leak: Our Experience at King Hussein Medical Center-Jordan. Scholars Journal of Applied Medical Sciences. 2020 Feb; 8(2):511513. doi: 10.36347/sjams.2020.v08i02.031

[19] Bertholet JW, Joosten JJ, Keemers-Gels ME, vanden Wildenberg FJ, Barendregt WB. Chest tube management following pulmonary lobectomy:

DOI: https://doi.org/10.54393/pjhs.v3i06.276

Change of protocol results in fewer Air Leaks. Interactive Cardiovascular and Thoracic Surgery. 2011 Jan; 12(1):28–31. doi: 10.1510/icvts.2010.248716

[20] Sivrikoz MC, Doner E, Tulay CM. Our Experience Using the Heimlich Valve and the Aseptic Space. Solunum. 2012; 14(2):73–8. doi: 10.5505/solunum.2012.0476