An update on the drainage of pyogenic lung abscesses

Siraj O. Wali

Abstract:
Most lung abscesses (80–90%) are now successfully treated with antibiotics; however, this conservative approach may occasionally fail. When medical treatment fails, pulmonary resection is usually advised. Alternatively, percutaneous transthoracic tube drainage or endoscopic drainage can be considered, though both remain controversial. In this communication, the medical literature focusing on percutaneous tube drainage efficacy, indications, techniques, complications, and mortality, as well as available data regarding endoscopic drainage are reviewed.

Key words:
Percutaneous drainage, pyogenic lung abscess, endoscopic drainage

Percutaneous transthoracic tube drainage was first described in 1938 for the treatment of tuberculous lung cavities.[1] It was later used routinely in the management of pyogenic lung abscesses before the antibiotic era and became the treatment of choice.[2,3] However, with the introduction of antibiotics, this procedure gave way to medical therapy. Although 80–90% of pyogenic lung abscesses are now successfully treated with antibiotics, this conservative therapy occasionally fails.[3-5] This may be due to the virulence of the responsible pathogens, failure to achieve an adequate concentration of antibiotics within the abscess cavity, and/or severe underlying lung disease that may play a role in the failure of the abscess cavity to drain spontaneously.[6,7] When medical treatment fails, pulmonary resection is usually advised. However, mortality rates from lung abscesses continue to be substantial, even with surgical therapy, ranging from 15 to 20%.[8-11] An alternative therapy in this context is percutaneous tube drainage (PTD). Currently, the role of PTD in the management of pyogenic lung abscess remains controversial. This procedure has not gained widespread popularity; it has been mainly reported in severely ill patients with lung abscesses, who are unable to tolerate lobectomy.[12] Another drainage procedure is endoscopic drainage (ED) of the parenchymal abscess cavities, which was first reported by Metras and Chapin in 1954.[13] ED is considered as an alternative to percutaneous drainage in patients who are coagulopathic, have airway obstruction, or have a fairly central abscess.

In this communication, we explore the medical literature focusing on PTD and alternative, potentially effective procedures. We identified and reviewed the English literature relating to this topic (January 1975 to December 2010) via a MEDLINE search using the following terms: Pyogenic lung abscess, treatment, percutaneous drainage, tube drainage, management, endoscopic drainage. Successful treatment was defined clinically as the control of sepsis and avoidance of surgical resection. Radiologically successful therapy was defined as resolution of signs of inflammation, namely, consolidation, pleural effusion, and cavities. The presence of a residual cavity did not indicate failure of drainage.

Percutaneous Tube Drainage

There have been 26 published studies of PTD in the English literature since 1975. However, none of these were controlled trials evaluating the role of PTD in the treatment of pyogenic lung abscesses. All the studies were case reports or case series. We excluded five studies (patients who were actually treated with pneumonostomy requiring operative rib resection or studies at the beginning of the antibiotic era).[14-17] The remaining 21 studies reported 124 cases, including 14 cases of secondary pyogenic abscess, 9 with pre-existing cysts and 5 with lung cancer. The remaining 110 patients had primary pyogenic abscesses.

The efficacy, complications, and mortality rate of PTD are summarized in Table 1. The success rate as defined above was 83.9% (104/124). The complication rate related to the procedure was found to be 16.1% (18/112). As a complication of the abscess, the overall mortality rate was estimated to be 4.0% (5/124).
Table 1: Efficacy, complications, and mortality of percutaneous tube drainage

| Year | Study                        | No. of cases | Success rate (%) | Complication rate (%) | Mortality rate (%) |
|------|------------------------------|--------------|------------------|-----------------------|-------------------|
| 1978 | Vainrub et al.[6]            | 3            | 100              | 0                     | 0                 |
| 1978 | Lawrence et al.[20]          | 1            | 100              | 0                     | 0                 |
| 1979 | Aronberg et al.[41]          | 1            | 100              | 0                     | 0                 |
| 1982 | Keller et al.[42]            | 1            | 100              | 0                     | 0                 |
| 1984 | Weissberg et al.[12]         | 7            | 100              | 0                     | 0                 |
| 1985 | Yellin et al.[18]            | 10           | 70               | 0                     | 0                 |
| 1985 | Mengoli et al.[19]           | 3            | 100              | 0                     | 0                 |
| 1987 | Crouch et al.[43]            | 4            | 100              | NA                    | 0                 |
| 1987 | Parker et al.[24]            | 6            | 83               | 50                    | 0                 |
| 1987 | Rice et al.[20]              | 11           | 72.7             | 0                     | 0                 |
| 1987 | Van Sonnenberg et al.[44]    | 4            | 75               | 0                     | 0                 |
| 1989 | Ball et al.[44]              | 3            | 100              | 0                     | 0                 |
| 1990 | Shim et al.[3]               | 5            | 100              | 0                     | 0                 |
| 1991 | Van Sonnenberg et al.[23]    | 19           | 100              | 21                    | 0                 |
| 1992 | Lambiase et al.[46]          | 2            | 100              | 0                     | 0                 |
| 1993 | Ha et al.[20]                | 6            | 66.7             | 0                     | 0                 |
| 1996 | Zuhdi et al.[47]             | 5            | 100              | 0                     | 0                 |
| 1997 | Johnson et al.[49]           | 1            | 100              | 0                     | 0                 |
| 1999 | Hoffer et al.[30]            | 5            | 80               | 40                    | 0                 |
| 1999 | Hirshberg et al.[6]          | 8            | 37.5             | NA                    | 5 (62.5)          |
| 2009 | Yonus et al.[29]             | 19           | 78.9             | 60                    | 0                 |
|      | Total                        | 124          | 104/124 (83.9)   | 18/112 (16.1)*        | 5/124 (4.0)       |

*See text for definition. In two studies,[8,43] the 12 patients with lung abscesses reported had no clear data regarding complications, and hence, were excluded from the total complication rate.

Indication

The main indication for PTD is when medical therapy fails, and it is required as a substitute for thoracotomy and lobectomy. PTD is particularly useful when the risks of surgery are prohibitive, but it may also be considered in patients who are actually clinically fit for surgery, as has been suggested by Yellin and colleagues.[18] These authors studied patients with primary pyogenic lung abscess during the years 1972 and 1982. Seven of these patients (14%) did not respond to conservative medical therapy and were candidates for lobectomy. All were treated with PTD and had complete recovery with no complications or relapse after a follow-up period of 2–5 years. Complete recovery following external drainage questions whether lobectomy is needed at all, especially if it involves resection of functional lung parenchyma and imposes much greater trauma than PTD. Indeed, several studies have reported that complications were greater after surgery than after tube drainage, despite the fact that patients treated with drainage were generally sicker, and hence, more liable to complications.[6,15,19,21] Postoperative mortality after surgery for lung abscess has been reported to range from 11 to 16%.[14,15] In contrast, the cumulative rate of mortality as a complication of a lung abscess treated with PTD was reported to be 4.8% in a previous review article.[22]

The size of the abscess itself is also a criterion indicating PTD, since patients with large abscesses are at a risk of aspiration of their own secretions. Surgical drainage of abscesses larger than 4–8 cm in diameter has been advocated by several authors.[19,20,23] In one study where the mortality of patients with lung abscesses was reviewed, 22% of 33 fatalities were attributed to aspiration of abscess contents.[19] More recently, larger abscesses were found to be associated with poor prognosis and increased morbidity, but not with increased mortality.[8] Accordingly, a more aggressive approach in treating such patients was recommended.

PTD is also indicated in debilitated patients having a cough that is poorly effective in achieving adequate spontaneous drainage.[23] This is particularly seen in an intensive care setting where patients are sedated, intubated, and mechanically ventilated.

Another possible indication for PTD is when the abscess cavity does not contain an air-fluid level and is homogeneous because some degree of tension may be present and sudden endobronchial decompression may be disastrous.[24] Moreover, avoiding massive hemoptysis may be a potential advantage of PTD. This may be achieved by providing prompt evacuation of the abscess contents, thereby stopping further growth of the cavity.[19] Although PTD is not usually recommended for the treatment of a lung abscess with massive hemoptysis, it may be considered for hemodynamically unstable patients not fit for lobectomy. This condition was described in one of the seven cases reported by Weissberg et al.[12] and PTD was successful in treating both sepsis and massive hemoptysis.

Before considering PTD in the event of failed medical therapy, it is important to rule out bronchial obstruction and bronchogenic malignancy since these are indications for surgical resection and not PTD. This can be achieved by bronchoscopy, which should be performed before attempting PTD. In the current review, however, only one third of the 124 cases had undergone bronchoscopy prior to PTD. Yellin et al.[18] reported three cases of lung cancer presenting with lung abscess in which PTD failed and a lobectomy was performed. Nevertheless, PTD may have a palliative role by relieving sepsis in the presence of unresectable lung cancer. This point was noted by Lawrence
et al.,[25] who described three cases of lung abscesses associated with unresectable lung cancer that were successfully treated, from the sepsis point of view, by tube drainage.

**Technique**

Drainage catheter insertion is usually performed under local anesthesia using either fluoroscopic, ultrasonographic, or computed tomographic (CT) guidance to avoid the uninvolved part of the lung. Radiographic guidance also helps in assessing pleural involvement, detecting loculated cavities, and determining the optimal position of the catheter.[26] However, it has been reported that PTD can be performed safely as a bedside procedure without imaging aids.[28] The hypothesis was that after a few weeks of medical treatment, the diseased area adheres to the chest wall, minimizing the risk of intra-pleural spread, and hence, the need for imaging guidance.[18] Once the catheter is in place and the abscess evacuated, gentle irrigation with normal saline is performed until the retrieved fluid is clear.[23] The tube is then connected to an underwater seal employing a negative pressure[12,19] or direct suction.[16,24] Periodic irrigation using 5–15 ml of normal saline should be performed daily.[19,24,26] Such irrigation may facilitate and expedite drainage.[19,21,27] The role of intra-cavity fibrinolytic agents in shortening the duration of percutaneous drainage is unknown. In a prospective, randomized study of patients with peritoneal, retroperitoneal, and parenchymal abscesses, Haaga and colleagues examined urokinase and saline as abscess cavity irrigants.[29] They concluded that although the remission rate was not different between the two groups, urokinase was effective in shortening the treatment time, and it improved the clinical course.[29] In addition, post-drainage contrast sinography may offer information on cavity closure,[23] although plain chest radiographs are normally sufficient for follow-up.[23]

There is a wide variation in the ideal size of the percutaneous tube to be used.[12,18,23,24,26] However, it is well established that a small tube of French size 10–14 can adequately and effectively drain pus.[13,24] In one report, a change in catheter from French size 7 to 10 was necessary in two patients to maintain adequate drainage.[24] Although the use of a large tube appears unnecessary since it may cause undesirable trauma to the lung,[23] it may still be indicated in patients with extremely tenacious and viscous material.[18,19]

**Efficacy and Safety**

Weissberg et al.[13] described seven patients with severe sepsis not suitable for surgery. Prompt clinical recovery post-PTD was reported in all patients with complete resolution of abscesses within 4–24 days without complications. Shim et al.[19] also reported the result of PTD in four patients with refractory lung abscesses; all patients defervesced promptly and all cavities closed over 6–12 weeks. The patients tolerated the tube drainage well and there were no side effects.[3]

Another advantage of PTD is rapid clinical and radiological improvements in pyogenic lung abscesses, and thus, the avoidance of potential complications associated with conservative and prolonged treatment. Van Sonnenberg et al.[25] reported a 100% cure rate in 19 unresponsive patients treated with CT-guided PTD. The average duration of drainage was 9.8 days, while hemothorax was reported in only one patient. Ha and colleagues reported complete abscess resolution in four of six patients treated with small catheters; the mean drainage duration was 15.5 days.[26] One of the remaining two patients showed a partial response and the other did not respond. The failure of PTD in the latter case was due to recurrent aspiration; no complications were related to the procedure itself.[26]

On the other hand, in one study, the incidence of secondary surgical resection after primary drainage was 11% in 295 patients.[19] This is close to twice the number seen among the 124 cases reviewed in this article, which was 6.5% (8/124); this indicates that PTD is becoming more effective, thus avoiding the need for more invasive procedures.

Although most studies demonstrated good results with PTD, it should be emphasized that the efficacy of this procedure is still being debated, and it is not always successful. Most recently, Yunus reported 19 cases with lung abscesses treated using CT-guided PTD.[29] The success rate was 79% and the complication rate, 60%. In a cohort study, Hirshberg and colleagues attempted PTD in 11 patients; the procedure was technically successful in eight patients only, and five of these patients died.[9] Factors that may lead to failure of PTD may include secondary lung abscess, co-morbid illnesses, virulent organisms, multiloculation, poor definition of the cavity, and a thickened wall cavity that may not collapse.[48]

Single percutaneous aspiration of abscess contents could also be therapeutically successful. In one study, after the failure of medical therapy, single percutaneous aspiration was performed in 10 patients.[30] Nine of these responded and recovered completely, while the remaining patient required percutaneous drainage.[30] In addition, percutaneous aspirate cultures were often diagnostic and informative, and hence, the treatment plan could be modified accordingly. Yang et al. described 10 patients (43%) whose antibiotic regimen was changed based on the results of percutaneous aspiration culture and sensitivity tests.[31] Seven out of 10 (70%) patients improved within 1–3 weeks with the new antibiotic coverage. It can therefore be concluded that aggressive interventional drainage can be of diagnostic as well as therapeutic value in managing lung abscesses.[31–34]

In summary, the overall success rate of PTD can reach 84% with a complication rate of 16% and associated mortality of 4% (which is much lower than that associated with surgery). This supports the efficacy and safety of PTD in the treatment of pyogenic lung abscesses.

**Timing and Duration**

The most suitable period for delay prior to PTD initiation remains unknown. However, refractory lung abscesses should not be left for too long without drainage.[12,25] A 10–14-day period of conservative medical therapy without clinical improvement has been suggested.[24] In cases of sepsis, deteriorating patient condition, or in conditions associated with a high mortality rate, the abscess should be drained without any delay.[8,12,20] Whether immediate PTD is indicated in the management of a large lung abscess without prior antibiotic therapy is unknown.
Complications and Mortality

In this updated review, clogging of the catheter necessitating tube exchange has been identified as a common complication of PTD, and is probably related to the use of small tubes.[23,24] Pneumothorax, hemothorax, and hemoptysis are potential complications. We identified reports of six pneumothorax cases but only one hemothorax case.[23,24,29] These complications may be related to the use of a standard chest tube and might be avoided by using a smaller one.[24] On the other hand, avoiding the puncture of normal lung parenchyma would also prevent pneumothorax and hemothorax.[23,24] In cases where abscesses are completely surrounded by normal lung parenchyma and require drainage, endoscopic tube drainage is probably a more suitable therapy. Contamination of the pleural cavity during the insertion of the drainage tube can also lead to empyema and bronchopleural fistula. Mengoli et al. reviewed 184 patients and reported persistent bronchopleural fistula in 19 patients (8%). Using imaging techniques to assess possible pleural symphysis and to determine a skin site closest to the abscess wall may reduce the risk of empyema.[20] However, despite using CT-guided PTD, Yunus reported two cases of empyema and bronchopleural fistula that required surgical intervention.[29] Other complications reported included chest pain and increased intracranial pressure.[23,30]

The overall mortality rate in this review was 4% (5/124), which is close to the rate reported in the last decade.[22] In a similar report that reviewed the literature from 1950 to 1985, the mortality rate was 13% in 694 patients treated with PTD.[19] This difference in mortality rates may be due to recent developments in PTD techniques, such as the use of smaller tubes and the abandonment of general anesthesia and rib resection, using more advanced imaging techniques, new developments in antibiotic therapies, differences in the type of patient treated (e.g., patients with different co-morbid illnesses and severities of infection), and/or a difference in the number of cases reviewed.

Endoscopic Drainage

Once medical therapy fails, the first consideration is PTD, as mentioned above. However, ED is an alternative to percutaneous drainage in patients with coagulopathies, those who have a fairly central abscess (where a significant amount of lung tissue needs to be traversed), and if other anatomic structures impede access to the cavity. In addition, there is always a concern of soiling the pleural space with the abscess contents in the case of PTD.[23] Thus, selected patients may be candidates for this procedure, such as those whose airway leads to an abscess or those in whom an endobronchial obstruction prevents drainage.[20]

Data regarding the efficacy of ED of parenchymal abscess cavities are scanty. This procedure was first reported by Metras and Chapin in 1954.[13] Since 1975, four more reports have been published. Altogether, 49 cases of pyogenic lung abscess with nine failures of endoscopic intervention have been described to date.[30-38]

The procedure requires standard flexible bronchoscopy.[39] Under fluoroscopic control, a guidewire is introduced into the cavity through the working channel of a flexible bronchoscope. Selective bronchography may be performed first to identify the airway leading into the cavity. In such patients, the guidewire is directly introduced through the bronchography catheter. When the guidewire is confirmed to be in place, the catheter and bronchoscope are removed. A pigtail catheter, 90 cm long and of a size of at least 7 F, is then slipped over the wire into the cavity. The correct position is checked with the application of contrast medium through the pigtail catheter. The guidewire is then removed and the catheter is secured at the nose. The abscess cavity is flushed twice daily with normal saline. Flushing with gentamycin in normal saline solution once a day has also been reported.[35] At all other times, the catheter is open to gravity drainage.

Endobronchial drainage has also been reported with the use of a laser. Transbronchial pigtail catheter drainage was used in three patients with refractory lung abscesses.[40] The catheter was introduced endobronchially via a bronchoscopic procedure. Laser was used to perforate the abscess wall through the airway into the abscess in order to provide a pathway for catheter insertion. An improvement in clinical and radiological parameters was noted immediately after catheter placement. The catheters were extracted after 4–6 days, and all patients had a complete clinical recovery.[40]

Conclusion

In conclusion, PTD is a safe and effective method for treating lung abscesses, and it is probably the invasive treatment of choice in a medically complicated patient who has failed medical treatment. PTD may also be considered as an alternative to lobectomy, even in patients fit for surgery. However, it is worth remembering that the evidence available regarding the efficacy of PTD is of level 5, that is, evidence is derived from uncontrolled case series, emphasizing the need for randomized trials. An alternative procedure to PTD is ED, particularly in coagulopathic patients, those with airway obstructions, or those with fairly central abscesses.

References

1. Neuthof H, Touroff ASW. Acute putrid abscess of the lung. Hyperacute variety. J Thorac Surg 1942;12:98-106.
2. Monaldi V. Endovacitary aspiration in the treatment of lung
abscess. Dis Chest 1956;29:193-201.
3. Shim C, Santas GH, Zelefsky M. Percutaneous drainage of lung abscess. Lung 1990;168:201-7.
4. Kosloske AM, Ball WS Jr, Butler C, Meseamech CA. Drainage of pediatric lung abscess by cough, catheter, or complete resection. J Pediatr Surg 1986;21:596-600.
5. Klein JS, Schultz S, Hefner JE. Interventional radiology for the chest: Imaging-guided percutaneous drainage of epidual effusions, lung abscess, and pneumothorax. AJR 1995;165:581-8.
6. Vainrub B, Mushrer DM, Guinn GA, Young EJ, Septimus EJ, Travis LL. Percutaneous drainage of lung abscess. Am Rev Respir 1978;117:153-60.
7. Mwandumba HC, Beeching NJ. Pyogenic lung infection. Factors for predicting clinical outcome of lung abscess and thoracic empyema. Curr Opin Pulm Med 2000;6:234-9.
8. Hirsberg B, Sklar-Levi M, Nir-Paz R, Ben-Sira L, Krivovuk V, Kramer MR. Factors predicting mortality of patients with lung abscess. Chest 1999;115:746-50.
9. Harber P, Terry PB. Fatal lung abscesses: Review of 11 years experience. South Med J 1981;74:281-3.
10. Hagan JL, Hardy JD. Lung abscess revisited. Ann Surg 1983;197:755-62.
11. Pohlson EC, McNamara JJ, Char C, Kurata L. Lung abscess: Surgical implications. Can J Surg 1980;23:297-302.
12. Weissberg D. Percutaneous drainage of lung abscess. J Thorac Cardiovasc Surg 1984;87:308-12.
13. Metras H, Chapin J. Lung abscess and bronchial catheterization. J Thorac Cardiovasc Surg 1954;27:157-9.
14. Deleans NC, Parson FG, Nelems JM, Cooper JD. Lung abscess: Surgical complications. Can J Surg 1980;23:297-302.
15. Estrella AS, Platt MR, Mills LJ, Shaw RR. Primary lung abscess. J Thorac Cardiovasc Surg 1980;79:275-82.
16. Cameron EW, Whitton ID. Percutaneous drainage in the treatment of Klebsiella pneumoniae lung abscess. Thorax 1977;32:673-6.
17. Lacey SR, Kosloske AM. Pneumonostomy in the management of pediatric lung abscess. J Pediatr Surg 1985;18:626-7.
18. Yellin A, Yellin EO, Lieberman Y. Percutaneous tube drainage: The treatment of choice for refractory lung abscess. Ann Thorac Surg 1985;39:266-70.
19. Mengoli L. Giant lung abscess treated by tube thoracostomy. J Thorac Cardiovasc Surg 1985;90:186-94.
20. Rice TW, Ginsberg RJ, Todd TR. Tube drainage of lung abscess. Ann Thorac Surg 1987;44:356-9.
21. Snow N, Lucas A, Hornigan TP. Utility of pneumonotomy in the treatment of cavitary lung disease. Chest 1985;87:731-4.
22. Wali SO, Shugaeri A, Samman YS, Abdelaziz M. Percutaneous drainage of pyogenic lung abscess. Scand J Infect Dis 2002;34:673-9.
23. van Sonnenberg E, D’Agostino HB, Casola G, Wittich GR, Varney RR, Harker C. Lung abscess: CT-guided drainage. Radiology 1991;178:347-51.
24. Parker LA, Melton JW, Delany DJ, Yankeskas BC. Percutaneous small bore catheter drainage in the management of lung abscess. Chest 1987;92:213-8.
25. Lawrence GH, Rubin SL. Management of giant lung abscess. Am J Surg 1978;136:143-9.
26. Ha HK, Kang MW, Park JM, Yang WJ, Shinn KS, Bahk YW. Lung abscess: Percutaneous catheter therapy. Acta Radiol 1993;34:362-5.
27. Stark DD, Federle MP, Goodman PC, Podrasky AB, Webb WR. Differentiating lung abscess and empyema: Radiology and computed tomography. AJR 1983;141:163-7.
28. Haaga JR, Nakamoto D, Stettler t, Novak RD, Gavan ML, Silverman SG, et al. Intracavitary urokinase for enhancement of percutaneous abscess drainage: Phase II Trial. AJR Am J Roentgenol 2000;174:1681-5.
29. Yunus M. CT-guided transthoracic catheter drainage of intrapulmonary abscess. J Pak Med Assoc 2009;59:703-9.
30. Hoffer FA, Bloom DA, Colin AA, Fishman SJ. Lung abscess versus necrotizing pneumonia: Implications for interventional therapy. Pediatr Radiol 1999;29:78-91.
31. Yang PC, Luh KT, Lee YC, Chang DB, YU CJ, Wu HD, et al. Lung abscesses: US examination and US-guided transthoracic aspiration. Radiology 1991;180:171-5.
32. Lorenzo RL, Bradford BF, Black J, Smith CD. Lung abscesses in children: Diagnostic and therapeutic needle aspiration. Radiology 1985;157:79-90.
33. Lee SK, Morris RF, Cramer B. Percutaneous needle aspiration of neonatal lung abscesses. Pediatr Radiol 1991;21:254-7.
34. Pena GN, Munoz LF, Vargas RJ, Alfageme MI, Umbria DS, Flores AC. Yield of percutaneous needle lung aspiration in lung abscesses. Chest 1990;97:69-74.
35. Herth F, Ernst A, Becker HD. Endoscopic drainage of lung abscesses: Technique and outcome. Chest 2005;127:1378-81.
36. Connors JP, Roper CL, Ferguson TB. Transbronchial catheterisation of pulmonary abscess. Ann Thorac Surg 1975;19:254-60.
37. Rowe LD, Keane WM, Jaafk BK, Atkins JP Jr. Transbronchial drainage of pulmonary abscesses with the flexible fiberoptic bronchoscope. Laryngoscope 1979;89:122-8.
38. Schmitt GS, Ohar JM, Kanter KR, Naunheim KS. Indwelling transbronchial catheter drainage of pulmonary abscess. Ann Thorac Surg 1988;45:43-7.
39. British Thoracic Society guidelines on diagnostic flexible bronchoscopy. Thorax 2001;56:1-21.
40. Shlomi D, Kramer MR, Fuku L, Peled N, Shitrit D. Endobronchial drainage of lung abscess: The use of laser. Scand J Infect Dis 2010;42:65-8.
41. Aronberg DJ, Sagel SS, Jost RG, Lee JJ. Percutaneous drainage of lung abscess. AJR Am J 1979;132:282-3.
42. Keller FS, Rosch J, Barker AF, Dotter CT. Percutaneous interventional catheter therapy for lesions of the chest and lungs. Chest 1986;21:407-12.
43. Crouch JD, Keagy BA, Delany DJ. “Pigtail” catheter drainage in thoracic surgery. Am Rev Respir Dis 1987;136:174-5.
44. van Sonnenberg E, Wittich GR, Edwards DK, Casola G, vonWaldenburg HS, Self TW, et al. Percutaneous diagnostic and therapeutic interventional radiologic procedures in children: Experience in 100 patients. Radiology 1987;162:601-5.
45. Ball WS Jr, Bisset GS 3rd, Towbin RB. Percutaneous drainage of chest abscesses in children. Radiology 1989;171:431-4.
46. Lambiase RE, Deyoe L, Cronan JJ, Dorfman GS. Percutaneous drainage of 335 consecutive abscesses: Results of primary drainage with one year follow up. Radiology 1992;184:167-79.
47. Zuhdi MK, Spear RM, Wothen HM, Peterson BM. Percutaneous catheter drainage of tension pneumatocele, secondarily infected pneumatocele and lung abscess in children. Crit Care Med 1996;24:330-3.
48. Johnson KM, Huseby JS. Lung abscess cause by Legionella pneumophila. Pediatric Lung Abscess. J Pediatr Surg 1983;18:625-7.