Chapter 5
Different Drainage Systems and Philosophies

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Recently the discussion about drainage systems and drainage philosophies was focussed on the question of "suction or no suction" with "no suction" meaning water seal. Proponents of "permanent suction therapy" are located mainly in Europe, whereas the American community promoted use of "water seal" as a separate therapy rather than being "no suction". With increasing knowledge concerning the pathophysiology of the pleural space this discussion has almost completely been brought to an end.

Different drainage systems and their drainage philosophies must be viewed in the historical context of a period of technical stagnation. Now with newer technologies, the management of the pleural space is better understood and treated appropriately.

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5.1 Definitions

5.1.1 Water Seal

Water seal works as a check or one way valve. Fluid and air is evacuated from the chest through the drainage system into the collection canister without the ability or hazard to go backwards (Fig. 5.1).

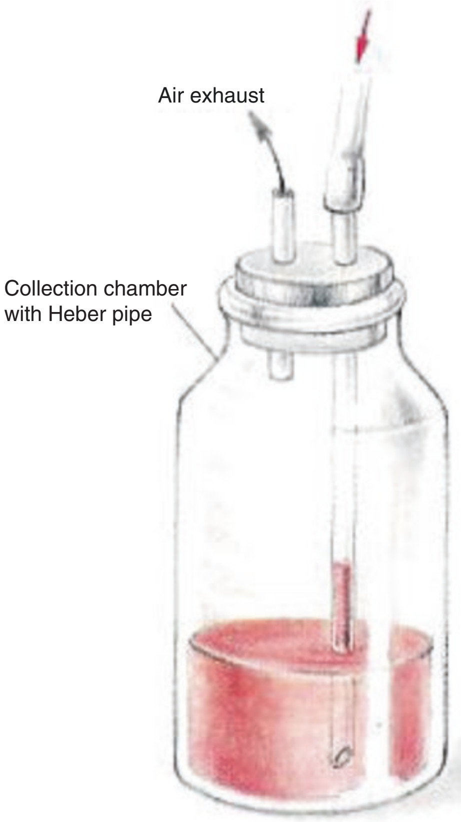

FIGURE 5.1 Water seal (From: G. Heberer, F.W. Schildberg, L. Sunder-Plassmann, I. Vogt-Maykopf Die Praxis der Chirurgie – Lunge und Mediastinum. Second edition. ISBN 3-540-19114-3, Page 191 ff)

Using a Heber-drain (see below), water seal is absolutely necessary, as the system uses an active, analogue suction source that the water seal represents. In the event of failure, an additional safety feature to prevent the patient from harm, such as a pneumothorax, is in place. In an electronic system, the check valve acts in the sense of a water seal, and is integrated into the system.

5.1.2 Heber-Drain

The Heber-drain is the classic gravity drain that works according to the so called Heber-principle using hydrostatic pressure (Fig. 5.2). When this is applied to a chest drainage system, the tubing is filled with fluid with the vertical height between chest cavity and collection canister determining the resultant subatmospheric pressure in the pleural space. In clinical practice, this means that having a patient in a bed and the canister on the floor causes a vertical height of about 60 cm. This results in a pressure in the pleural space of minus 60 cm of water.

When using a Heber-drain, it is mandatory that the collection canister is placed below the level of the chest!

A Heber-drain is always combined with a water seal component.

A Heber-drain or a water seal collection canister is without an active suction source. This system always generates a subatmospheric pressure in the pleural space dependent on the vertical height between the chest and the collection canister. This is usually a distance of 60 cm with the patient in bed with the canister on the floor causing minus 60 cm of water. It is assumed that the tubing is partially filled with fluid.

5.1.3 Bülau-Drain

The Bülau-Principle was developed by the pulmonologist Gotthard Bülau (1835–1900) in Hamburg. He used this

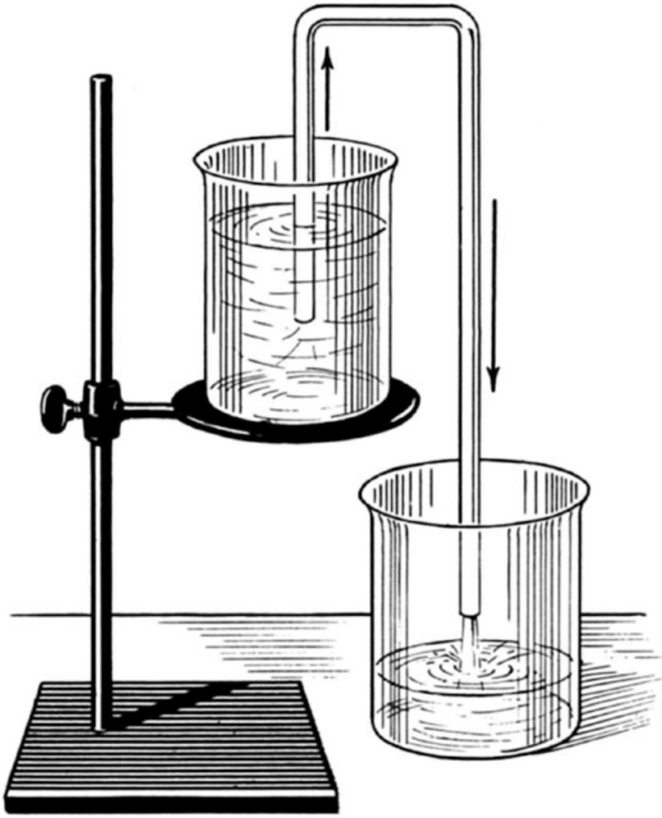

FIGURE 5.2 Heber-principle

principle for the first time in 1875 to treat a pleural empyema. The Bülau-principle is based on the application of a permanent passive suction generated by an Heber-system within a closed system (Fig. 5.3).

A Bülau-principle is a therapeutic drain using permanent passive suction generated by a Heber-drain rather than a particular catheter or drainage system.

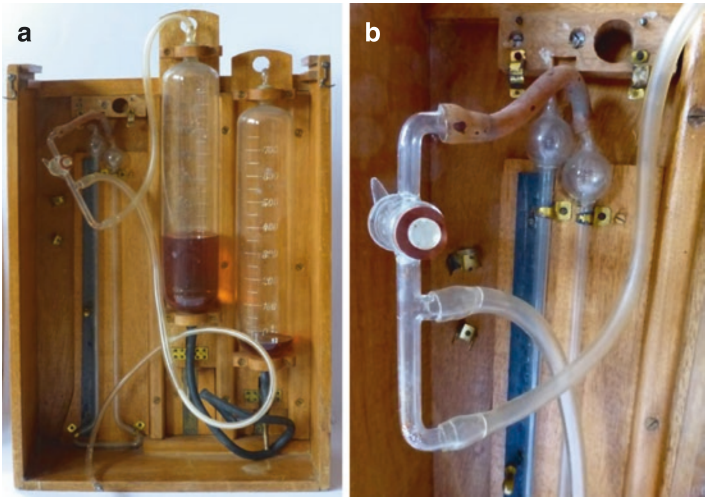

FIGURE 5.3 (**a**) and (**b**) Bülau-Drain-System

5.1.4 Monaldi-Drain

Vincenzo Monaldi (1899–1969) first described chest tube insertion in the second intercostal space in the midclavicular line. According to the author, this localization should be avoided as the intercostal spaces in that area are very narrow leading to pain when chest a tube is placed there. The skin incision is also in a very visible region where scars can develop keloids and are unsightly. There was a drain used for the therapy treatment of pulmonary abscesses named the "Monaldi-drain".

5.1.5 Heimlich-Valve

A Heimlich-valve (Fig. 5.4) is a check or one way valve that was named after the American physician Henry Heimlich who was born in 1920. Due to the integrated rubber lip in

FIGURE 5.4 Heimlich-valve

device, fluid and air are allowed to escape from the chest into the collection bag. Fluid and air are unable to reflux in the opposite direction as the rubber lip will collapse making such transit impossible.

Heimlich-valves can be used if there is a relatively small but persistent air leak in a mobile patient with minimal fluid production. In emergency situations such as a tension pneumothorax), the Heimlich-valve is a safe and simple but effective tool. In Germany it is part of the standard equipment in rescue vans.

In German speaking regions, the Heimlich-valve is used less often than in the American world as the length of stay due to many non-medical reasons is much shorter compared to Europe or Germany.

5.2 Drainage Systems

Before discussing different drainage systems, one must consider some basic requirements that a clinicians will ask for today in such a system. The following criteria must be fulfilled:

1. The system is simple and safe
2. The different components are simple, easy, and fast to assemble
3. The system can be used for all chest drain indications

4. Mobility of the patient is guaranteed
5. The system is reliable
6. The system is quiet
7. The system is light weight
8. The system is cost effective

This list includes safety issues [1–5], aspects of patient's comfort [6, 7] as well as economic points that have become more and more important.

In regards to #3, the possibility of ubiquitous use is also a safety issue as the use of a single system in a hospital will increase patient's safety due to familiarity and availability.

5.2.1 One-Chamber-System

A one chamber system consists of the collection canister (Fig. 5.5) that in convention includes a water seal component with the possibility to evacuate air (actively or passively) towards the atmosphere. In the new electronic devices, the collection chamber is directly connected to the suction source where a check-valve is integrated.

In theory, the majority of indications for chest drainage can be fulfilled with a one chamber system. Such a system can be used as a Heber-drain or in combination with an active suction source. There is a limitation with conventional systems that include a collection canister and suction source from different suppliers when there is a huge air leak.

When using a one chamber system such as a Heber-drain (no active suction), the fluid must be manually milked down to the canister because there is a potential for air to not be able to escape depending on the pressure gradient. Remember the difference in height between the canister and patient determines this pressure. This could mean that the patient would not be able to evacuate air just by breathing and/or coughing which could cause a pneumothorax and possibly subcutaneous emphysema.

The occurrence of a so called "siphon-effect" (see below) must also be prevented.

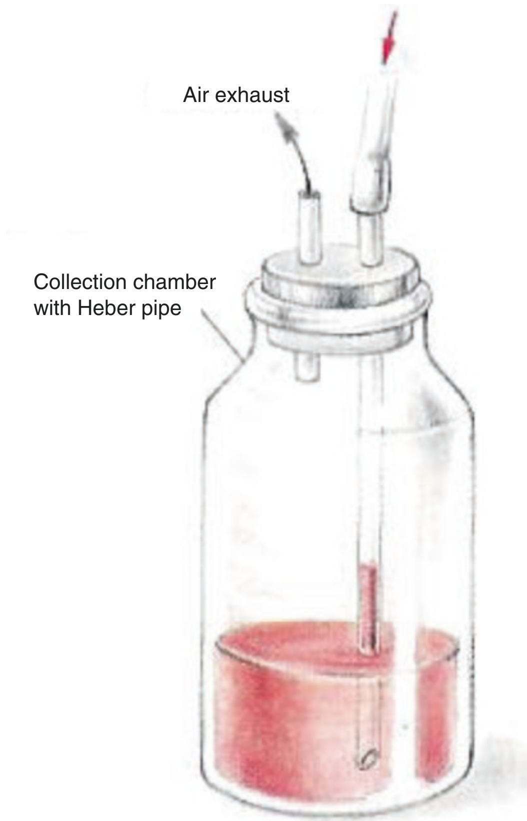

FIGURE 5.5 One-chamber-system (From: G. Heberer, F.W. Schildberg, L. Sunder-Plassmann, I. Vogt-Maykopf Die Praxis der Chirurgie – Lunge und Mediastinum. Second edition. ISBN 3-540-19114-3, Page 191 ff)

Modern electronic systems in which the canister is integrated into the system do not have these same limitations as they are in effect a two chamber system. This is achieved with the geometry of the tubing and the connections that are in place. When entering the system, fluid and air are separated with fluid into the collection chamber and air evacuated through the system into the atmosphere.

5.2.2 *Two-Chamber-System*

Two chamber systems were developed to prevent foam formation which is due to protein rich surfactant seen in patients with a large air leak. There can be a lot of foam in a one chamber system with water seal which can make the observation and quantity of an air leak more difficult or even impossible to see. The two chamber system also prevents that from rising up in the tubing towards the patient.

Fluid and air are directed via tubing to the collection canister where fluid falls due to gravity. The air moves forward to the second canister that has the water seal and then is evacuated either actively or passively (Fig. 5.6).

5.2.3 *Multi-Chamber-System*

Multi chamber systems, mostly three chamber, were developed during the time where there were no mobile suction sources available. The only suction source available in a hospital was wall suction delivered by the so called central vacuum with a pressure of minus 100 cm of water. In earlier days there had been no pressure relief valves available to decease the negative pressure to a therapeutic level.

In addition to the two chamber systems, a third chamber, the water-vacuometer chamber, was linked. This closed chamber was filled with water where a pipe was plugged in. The deeper the pipe depth, the bigger the subatmospheric pressure generated in the pleural space (Fig. 5.7).

In the very beginning these systems had been created by adding a third glass bottle. These systems were very bulky and accident laden. Eventually, commercial suppliers developed and sold these systems. Thanks to modern technical possibili-

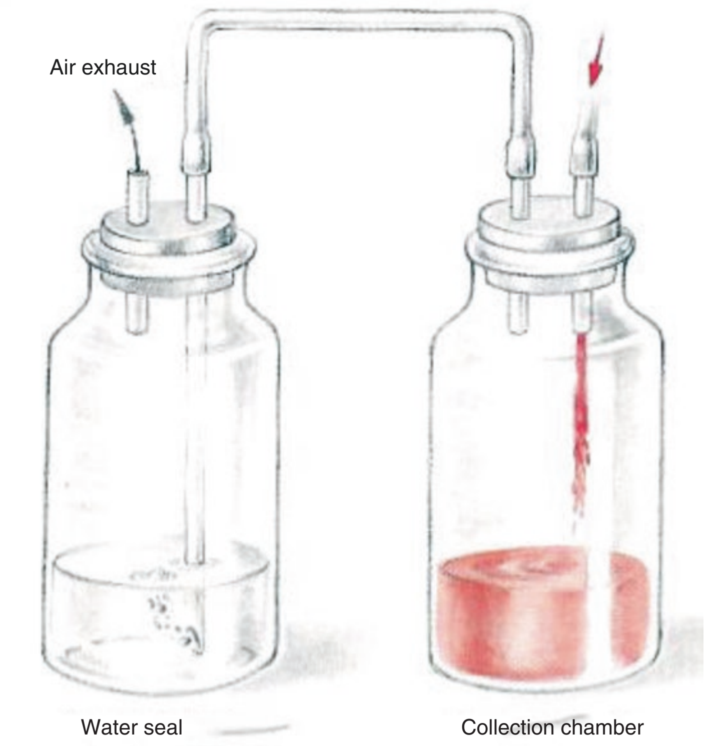

FIGURE 5.6 Two-chamber-system (From: G. Heberer, F.W. Schildberg, L. Sunder-Plassmann, I. Vogt-Maykopf Die Praxis der Chirurgie – Lunge und Mediastinum. Second edition. ISBN 3-540-19114-3, Page 191 ff)

ties, there is really not a need for these systems anymore. Most of the commercially available multi-chamber-systems need high flows (up to 20 l/min) to be able to work due to their mechanics.

Multi chamber systems that are commercially available today date back to earlier systems that were needed due to a lack of technical alternatives. Today there is no more need for such systems as superior alternatives exist.

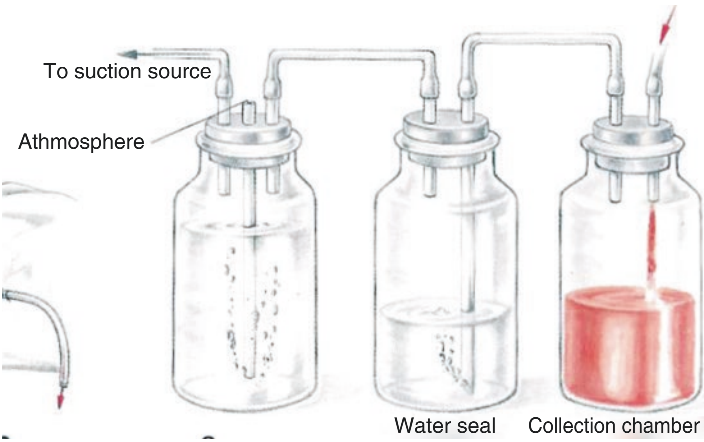

FIGURE 5.7 Three-chamber-system (From: G. Heberer, F.W. Schildberg, L. Sunder-Plassmann, I. Vogt-Maykopf Die Praxis der Chirurgie – Lunge und Mediastinum. Second edition. ISBN 3-540-19114-3, Page 191 ff)

5.2.4 *Electronic Systems*

Over the recent past, electronic systems (Fig. 5.8) have become commercially available which allow the collection chamber to be integrated into the system. This has allowed for minimization of the system which has aided in patient mobilization. The addition of observation software has made possible the generation of objective data concerning air leaks and fluid production for real time data collection. The monitor is as close as possible to the pleural space as it is located in the connecter between catheter and the system's tubing (Fig. 5.9).

The tubing used in these electronic systems is made of a double lumen which allows for the separation of air and fluid. The thinner tube of double lumen tubing is used for pressure measurement in the pleural cavity. In an ideal word, although technically possible but not currently commercially available,

FIGURE 5.8 Electronic system (Illustration printed with permission from Medela)

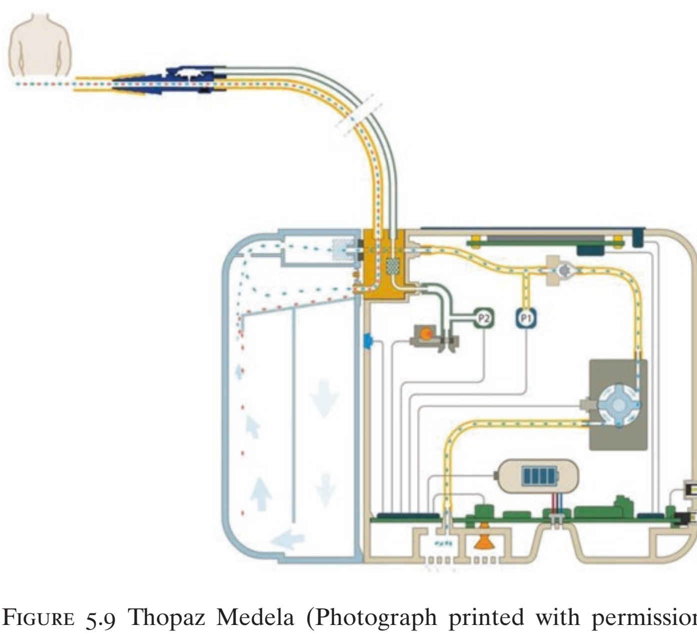

FIGURE 5.9 Thopaz Medela (Photograph printed with permission from Medela)

the pressure measurements would be from the intrapleural cavity. Experimental studies show that the data received next to the pleural space comes quite close to measurements in the pleural space [1].

With the ability to acquire, store, and interpret objective data from these electronic systems, is has become apparent that healing is dynamic process. Numerous studies have shown that using this information, the chest drainage time after anatomic resections can be shortened by 1 day on average [2–5].

Measurement of an air leak (alveolo-pleural fistula) follows the "paddle-wheel principle". This means that according to the rotation speed of the integrated paddle-wheel (Fig. 5.9) a mathematical algorithm is able to calculate very precisely the amount of air that is being drained. This is represented on the display as the flow in ml/min. After one hour, a graph is visible showing the course of the leak over the time based upon this data.

Another very important aspect of the measurement is the fact that objective data is generated which is not dependent on the observation and interpretation of the engaged staff. It has been shown [6, 7] that discrepancies in evaluation of the clinical course are significantly lower when using an electronic system compared to conventional systems.

Monitoring and alarm features increase the safety of the treatment and reduce the work load of the nursing staff [8].

It is important that such a system is not just a "pump" applying "permanent suction" to the pleural space. In fact, the pleural space is monitored and the system intervenes only as needed to achieve the desired value. This is shown in that the "pump" in the system has only 90 min of drainage time during the 2.5 days after an uncomplicated lobectomy.

5.3 Drainage Philosophies

There are a couple of definitions that are used in the clinical setting that are sometimes used in an incorrect way and therefore need clarification.

5.3.1 Negative Pressure

From a physical standpoint “negative pressure” does not exist! This is intended to express a difference in pressure between two spaces and in these cases means between the atmosphere and the pleural space. To be correct this means that were are referring to a subatmospheric pressure in the pleural space rather than “negative pressure” [9].

5.3.2 Vacuum

Very often it is said that a “vacuum is applied” or “a vacuum is generated”. The precise definition of “vacuum” is a space with zero pressure (i.e. the universe) [9]. This is a situation that we do not achieve with our drainage systems!

5.3.3 Active vs. Passive Suction

The wording “passive suction” was widely used when referring to the drainage of air and fluid as the intrappleural pressure is higher than the atmospheric pressure. According to the consensus paper from 2011 [10] we are now talking about “no external suction”.

To drain in an active manner, a subatmospheric pressure at the tip of the catheter has to be generated. According to the consensus paper [10] active suction refers to external suction.

5.3.4 Regulated vs. Unregulated Suction

Old fashioned drainage systems that were commercially available allowed for regulation of suction in the system, but did not suction subatmospheric pressure in the pleural space!

Regulated suction in the canister means unregulated suction in the pleural space. Water seal is always an uncontrolled, unregulated, potentially unknown suction in the pleural space.

FIGURE 5.10 Siphon

5.3.5 *Siphon*

As the tubing creates a sagging loop filled with fluid (Fig. 5.10) the subatmospheric pressure that results in the pleural space is reduced due to the vertical height of that fluid column. Using a drainage system with an active suction source set on minus 20 cm of water and with the fluid in the syphon rising up 10 cm as well, the resulting pressure in the pleural space is just minus 10 cm of water! In actuality the siphon effect will be more than 10 cm of water. With all of these analogous systems, we don't know the exact subatmospheric pressure that results in the pleural space because we only know the pressure set in the system.

On the other hand, when using a Heber-drain (permanent passive suction), the patient lying in bed with the canister on the floor generates a subatmospheric pressure in the pleura space of 60 cm of water. This is due to the 60 cm of difference in vertical height between floor where the canister sits and where the patient is positioned in the hospital bed.

These problems do not occur when using an electronic system because the measurements are taken as near as possible to the pleural space at the connection between the tubing and catheter. This is the reason why the electronic system works correctly irrespective of where it is placed (on the floor or above the chest).

5.3.6 Drainage Philosophies

Traditionally there were two drainage philosophies which included permanent suction and no suction. There are numerous studies [11–14] with regard to the question whether suction is harmful or helpful in treating air leaks. These studies and the author's own clinical experience have shown that in most cases the decision has to be made in an individualized fashion. The components that help in the decision making process include the patient's underlying disease, status of the lung tissue ("normal", fibrotic, emphysematous), timing, and the surgical procedure.

The mindset of "either or" is antiquated. Thanks to modern electronic drainage systems, there is a better understanding of what is going on the pleural space. This knowledge supports an individualized approach to the intrapleural space.

The goal of chest tube therapy is to restore the normal physiological status of the intrapleural space.

5.3.7 Management of the Pleural Space

Today we are talking about the management of the pleural space. Clinicians have tried applying different subatmosheric pressure settings in patients with different anatomic resections (right upper lobectomy vs. left lower lobectomy). However, until today, the clinical relevance of these rather theoretical considerations had not been proven [15].

With the advent of the electronic drainage systems, we are now able to monitor the pleural space. The system only intervenes as when the measured value and the set differ. The system generates a subatmospheric pressure thus evacuating air from the pleural space as long as the set value is reached.

As you can see, the discussion is no longer "suction or no suction". Instead the discussion is more about which system configuration is an optimal solution for an individual patient. The hope is that this discussion will allow for the safest and most efficient therapeutic algorithms to be generated for future patients.

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