INDEX

1. Anatomy and physiology
2. Function of a chest drain
3. Types of chest drains
   3.1 Water seal system
   3.2 Three chamber system
   3.3 Dry seal system
   3.4 Dry suction system
   3.5 Digital drainage systems
1. ANATOMY & PHYSIOLOGY

Each lung is surrounded by two layers, the visceral pleura (inner layer) and the parietal pleura (outer layer). The visceral pleura surrounds the lung and the parietal pleura lines the inside of the ribs/chest wall. The two layers are separated by a potential space, the pleural space, that contains just enough lubricating fluid for the two layers to move relative to one another during breathing. Although the pleural pressure fluctuates with breathing, it is always a negative value, i.e. -5 to -9 cmH₂O pressure.

The pleurae can be punctured either from the inside, by e.g. a fractured rib, or from the outside, by e.g. a gun shot wound. When this occurs, the lung collapses due to an accumulation of air (pneumothorax) or blood (haemothorax) in the pleural space. The lung may also collapse when fluid, such as pus (empyema) or serous fluid (pleural effusion) accumulate in the pleural space. A collapsed lung loses its ability to exchange carbon dioxide and oxygen.

Figure 1: Anatomy of the lungs

Figure 2. Air and fluid accumulation in pleural space
Tension pneumothorax, a life-threatening condition, occurs when trapped air in the pleural space produces a positive pressure that causes compression of the heart and other structures in the mediastinal space; producing a mediastinal shift towards the opposite side of the chest. This restrains the functioning of the heart and may deteriorate to cardiac arrest. Treatment consists of urgent needle decompression of the pleural space followed by insertion of a chest drainage device.

Figure 3. Tension pneumothorax with mediastinal shift

2. FUNCTIONING OF A CHEST DRAIN

In order to remove trapped air and/or liquid form the chest, a drainage tube (thoracic/chest catheter) is surgically inserted into the pleural, mediastinal or pericardial space. This catheter is connected to a chest drainage device, such as the Sinapi chest drain.

The main function of a chest drain is to allow fluid and air to exit the chest but not to return. The way in which this can be accomplished, ranges from a simple single chamber to a large and complex three chamber system. Liquid and air escape from the pleural space via the catheter and drains into the chest drainage device, allowing gradual lung re-expansion and restored functioning of the lungs.

The greatest risk to the patient, when using chest drainage devices, occurs when its ability to drain air/liquid is impeded, resulting in either tension pneumothorax (pleural drain) or cardiac tamponade (mediastinal/pericardial drain). Making use of tubes with large internal diameters and avoiding the use of tube clamping devices (slide clamps) reduces the occurrence of both these life-threatening conditions.

The secondary functions of a chest drain are:

- Creating a bacterial barrier
- Storing drained fluids
- Providing a way to attach the unit to an external suction source
- Indicating an air leak (bubbling)

3. TYPES OF CHEST DRAINS

3.1 WATER SEAL SYSTEM (single chamber)

![Figure 4. The standard Under Water Drain (UWD)](image)

First described in the literature in the early 1900’s, an ‘underwater drain’ consists of a bottle that is filled with sterile water to a height of approximately 2 cm. A rigid pipe, secured in the lid of the bottle, extends vertically to just below the water level, creating a 'water seal/valve'. The other end of the pipe that protrudes above the lid, is connected to a silicone tube which in turn is attached to the chest catheter, positioned in the pleural space. Air or liquid that drains from the pleural space, exits the pipe in the bottle and due to the weight of the water, is prevented to return to the pleural cavity during expiration. (It is, however, not as efficient as a mechanical valve and some air does return to the chest.) As drained fluid accumulates in the bottle, the opening pressure of the water seal (or valve) increases in proportion to the depth at which the tube exits beneath the water level which reduces the speed at which subsequent fluid is able to drain.

The perceived simplicity of this system contributed to its acceptance by the market and it is still used in many hospitals worldwide. Components are relatively easy to manufacture, making it an affordable option. The need to find an alternative to the single chamber water seal system stemmed from the need for external suction and suction regulation as well as a desire for more efficient fluid drainage.

![Figure 5. Fluid collecting in loops and in bottle impairs drainage](image)
3.2 THREE CHAMBER SYSTEM

In response to this, the three chamber system was developed. The first chamber functions as a collection chamber for fluid. Air therefore moves from this chamber to the second chamber that fulfils the function of a water seal. The benefit of adding a second chamber is that the first chamber may fill up with fluid without affecting the opening pressure of the water seal in the second chamber (as happens in single chamber systems). The third chamber functions as a suction regulator. (External suction pressure is generally too high to attach directly to a chest drainage device and should be regulated between -10cmH2O pressure and -50cmH2O pressure.) The third chamber is fitted with a tube open to atmosphere (adjustable vent tube). When external suction is applied, air may be sucked into this tube and bubble through the water. If the bubbles are not too vigorous (i.e. the wall suction level is not set too high) the effective suction force is equal to the depth (in cm) of the vent tube below the water level.

![Diagram of three chamber system](image)

*Figure 6. Functioning of the three chambers*

The greatest disadvantages of the three chamber system is its complexity, difficult set-up and its bulkiness, affecting patient mobility. Alternatives to the system include combining chamber 1 and 2 and reducing the size of chamber 3 (i.e. Grena Medical chest drain), thus creating a more compact and mobile system. Manufacturers have also combined the three chambers into one unit to allow for mobility and patient transport.

3.4 DRY SEAL SYSTEMS

The most obvious disadvantage of a water seal is that the closed system is disrupted when the unit over turns, resulting in a potential lung re-collapse or pleural infection. The water seal system is furthermore an ineffective valve due to water being able to move toward the patient during expiration, thus impairing the regeneration of negative intra-pleural pressure.

In order to address these shortcomings, some manufacturers have opted for a dry seal alternative. Most of these units contain a diaphragm valve that is capable of draining air despite a large flow resistance. It is however not capable of draining blood or blood clots and will almost certainly block if used for this purpose. For this reason the diaphragm valve
must be positioned after the collection chamber so that only air will drain through it. This, however, results in a large amount of air (dead space) between the valve and the patient which prevents effective evacuation of air & blood by gravity force. Consequently units must be attached to external wall suction initially to generate sufficient negative pressure to facilitate drainage.

A better alternative is to use a flutter valve (Heimlich or Scheffler valve) positioned before the collection chamber. Depending on manufacturer guarantee and recommendation, flutter valves are capable of draining both fluids and air while maintaining a low flow resistance and without an increase in opening pressure and the risk of blockage. With the use of a dry-seal valve the regeneration of negative intra-pleural pressures occur faster, sometimes within hours and often without the need for external suction. These systems may be orientated freely without losing functionality and a tap can be included to enable emptying of content, resulting in light, compact units. Patient mobility is facilitated which in turn leads to an increased oxygen demand and subsequent increased tidal volume. The latter increases the positive pressure inside the lung and pushes air and fluids out of the pleural space, speeding up lung re-expansion.

Clinical evidence confirms that mechanical (dry seal) valves regenerate negative intra-pleural pressures faster, reduce chest drainage time (as well as total number of chest X-rays) and ultimately hospital stay. (These clinical studies were performed over an extended period of time on different continents.)

### 3.5 DRY SUCTION SYSTEM

In order to produce chest drain units that are more compact and light, manufacturers developed suction regulators that function without water. These typically include a diaphragm and spring combination that self-regulate according to the setting at which the suction regulator is set. Another advantage of dry suction systems is that it can achieve higher suction forces than water seal systems - sometimes up to -50cm H2O. Dry suction systems can be orientated freely while maintaining functionality.

*Figure 7: A typical suction regulator mounted on a chest drain unit*
3.5 DIGITAL DRAINAGE SYSTEMS

The latest addition to the chest drainage range is the digital chest drain. It consists of a mobile suction pump, digital screen and disposable drainage container and tubing. The unit monitors, displays and records air-leaks over time. It has alarm functions and auto-regulated suction to ensure that suction force stays constant despite e.g. the accumulation of drainage in dependent tubing loops. Manufacturers claim improved patient mobility, measurement of suction force at the chest catheter connector and tracking of air-leak over time which serves as a guide in terms of chest drain removal. Clinical studies prove shorter drainage time, easy indication of reduction in air-leak and shorter hospitalization time. (Many of these clinical studies are declared as sponsored by manufacturers.)

![Digital drainage unit](image)

*Figure 8. Digital drainage unit*

Measuring the size of an air-leak over time, is especially beneficial in prolonged air-leak. It is also valuable in research settings. Few clinicians, however, will remove a chest catheter before an air-leak has completely resolved. The in-line suction bulb of the Sinapi chest drain provides similar (qualitative) feedback in terms of determining when to remove a chest catheter: if the bulb, situated above the valve, remains depressed over time (maintains a negative intra-pleural pressure) it indicates that there is no further drainage form the intra-pleural space.

In terms of suction, all chest drain systems fitted with suction regulators auto-regulate suction and, as long as fluids are not collecting in tubing loops, the regulated suction will be accurate. Although manufacturers of Digital chest drains claim improved patient mobility, the suction pump of digital drains is, in fact, heavy and difficult to carry, especially by frail patients. Lastly, the consumables of digital drainage systems are expensive and the capital equipment must be purchased and maintained.