I Pneumoperitoneum: Physiologic effects

Laparoscopic surgery requires the insufflation of the abdominal cavity for visualization and working space. The most common gas used for insufflation is CO_2 because it is colorless, non-flammable, and non-toxic. Insufflation is usually maintained at an intra-abdominal pressure (IAP) between 10-15 mmHg (normal <5mmHg). The physiologic effects of insufflation are the result of an increase in intra-abdominal pressure (IAP) and the systemic absorption of CO_2.

Respiratory Effects: The pulmonary effects of insufflation mainly relate to the increase in IAP. Pneumoperitoneum displaces the diaphragm cephalad causing a decrease in functional residual capacity (FRC). This results in airway collapse, atelectasis, and V/Q mismatch. A mild respiratory acidosis is frequently observed. Trendelenburg positioning can further potentiate the decrease in FRC.

Cardiovascular Effects: Pneumoperitoneum can result in significant hemodynamic derangement. During insufflation, venous return (VR) to the heart is decreased secondary to compression of the inferior vena cava (IVC). Systemic vascular resistance (SVR) is typically elevated as a result of catecholamine release and direct effects of increased IAP. Thus, cardiac output can be as much as 30% decreased due to increased afterload and decreased preload. Patients with cardiac disease or hypovolemia are more prone to these affects.

Renal Effects: Insufflation results in decreased renal blood flow (RBF) and increased vascular resistance leading to decreased GFR. These effects are temporary.

Gastrointestinal: Insufflation may lead to an increased risk of regurgitation and aspiration of gastric contents.

Abdominal Laparoscopy: Complications

Advanced, Clinical Subspecialties

Laparoscopic surgeries are usually performed over open surgeries because laparoscopic procedures are less invasive, which allows for early recovery and return to normal activities. Laparoscopic surgery is not indicated for patients who are unable to tolerate increased intraabdominal pressure and patient who cannot tolerate the potential respiratory or cardiovascular complications listed below. This may include patients with severe COPD, prior upper abdominal surgery, or severe cardiac disease.

Intraabdominal insufflation (high intraabdominal pressures) can lead to:

Respiratory complications (due to cephalad displacement of the diaphragm):

1. Atelectasis
2. Decreased FRC
3. Increased PIP
4. Increased $PaCO_2$
5. Decreased PaO_2

Cardiovascular complications:

6. Decreased venous return
7. Decreased CO à increased SVR
8. Decreased blood flow to the splanchnic and renal circulation à decreased UOP

Other complications:

Pneumothorax secondary to retroperitoneal dissection by insufflated CO_2. Subcutaneous emphysema. Hemorrhage due to vascular injury from trocar placement. Vascular injection of CO_2 (VAE)

II. Abdominal Compartment Sy

Patient Population: Occurs predominately in patients in profound shock, in patients requiring large amounts of vasopressors, resuscitation fluids and blood , in patients who require abdominal packing for abbreviated/staged laparotomy, and in those with major visceral or vascular abdominal injuries.

1. Sudden increase in intra-abdominal pressure
2. Increased peak inspiratory pressure
3. Decreased urinary output despite adequate CO
4. The 3 H’s (Hypoxia secondary to increased airway pressures, Hypercapnia, and Hypotension secondary to decreased venous return to the heart.)

Diagnosis : Confirmed by measuring bladder pressure, which ultimately represents intra-abdominal pressure. The level of IAP at which ACS occurs is patient specific, and thus the diagnosis (and treatment) is based on the patient’s physiologic response to increased IAP. Most patients with IAP between 25 and 35 mm Hg (grade III) ultimately require decompression. All patients with IAP greater than 35 mm Hg (grade IV) require immediate decompression because this group of patients may deteriorate to cardiac arrest at any time.

Treatment : Rapid decompression of the elevated intra-abdominal pressure by opening the abdominal wound and performing a temporary closure of the abdominal wall with mesh or a plastic bag (Bogota bag).

Physiologic consequences of persistent elevated intra-abdominal pressure:

DECREASED

- Cardiac output
- Central venous return
- Visceral blood flow
- Renal blood flow
- Glomerular filtration

INCREASED

- Cardiac rate
- Pulmonary capillary wedge pressure
- Peak inspiratory pressure
- Central venous pressure
- Intrapleural pressure
- Systemic vascular resistance

Capnothorax: Diagnosis

Advanced, Clinical Subspecialties

Capnothorax is a type of pneumothorax where carbon dioxide occupies space in the pleural cavity preventing full inflation of the lung. Capnothorax is suspected in the setting of abdominal laparoscopic surgery when CO2 is used for insufflation and the procedure involves manipulation of the diaphragm as in esophageal surgery. In most cases of pneumothorax, etCO2 gradually decreases as the relative shunt created by the air in the pleural space prevents alveoli expansion and gas exchange. In a capnothorax, however, etCO2 gradually increases as carbon dioxide in the pleural space is absorbed and exchanged. Other diagnostic clues include absent or decreased breath sounds on the side of the pneumothorax, increasing etCO2 despite compensatory increases in minute ventilation, gradually increasing mean airway pressure, decreasing oxygen saturation, and chest Xray showing pneumothorax. When capnothorax is suspected, pneumoperitoneum should be released and 100% FiO2 administered until oxygen saturation recovers. Chest Xray can confirm the diagnosis and thoracentesis should be pursued in cases of large pneumothorax or pneumothorax unresponsive to conservative management.

Sources

1. Ghodki PS, Thombre SK. Capnothorax during laparoscopic fundoplication: Diagnosis and anesthetic management. J Acad Med Sci [serial online] 2012 [cited 2019 May 5];2:118-20.

III. Lung ultrasonography: Signs

Advanced, Basic Sciences, Clinical Subspecialties

Lung ultrasound is a group of point-of-care bedside exams, which has the following potential applications: (1) diagnosis of pneumothorax; (2) diagnosis of interstitial syndrome; (3) diagnosis and differentiation of underlying cause of pleural effusion, and selecting the optimal puncture site for pleurocentesis; (4) diagnosis of pulmonary consolidation and pneumonia; (5) diagnosis of atelectasis; (6) diagnosis of pulmonary edema and differentiation from acute respiratory distress syndrome (ARDS); (7) diagnosis of pulmonary embolism; (8) monitoring of lung disease (severity, progress, and response to therapy); (9) optimizing mechanical ventilation.

Normal lung sonographic signs:

1. Lung sliding sign is sliding of visceral and parietal layers of pleura with respiration.

2. Seashore sign is a complex picture of parallel lines signifying the static thoracic wall and sandy “granulous” pattern, which reflect the normal pulmonary parenchyma.

3. A-lines are horizontal artifact indicating a normal lung aeration.

Pathological lung sonographic signs:

1. B-lines represent discrete laser-like vertical hyperechoic lines that arise from the pleural line and extend to the bottom of the screen. These lines are consistent with interlobular pulmonary edema and can be found in both ARDS and cardiogenic pulmonary edema.

2. Dynamic and static air bronchograms which consist of hyperechoic punctiform elements within the lung parenchyma that can be used to diagnose consolidation and atelectasis, respectively.

3. Lung pulse is an early and dynamic diagnostic sign of complete atelectasis, in which US perceives the vibrations of heart activity, along with the absence of lung sliding.

The International Liaison Committee on Lung Ultrasound (ILC-LUS) has recommended the following signs for the detection of various lung abnormalities.

• Pneumothorax: Absence of lung sliding, presence of lung point(s), absence of B-lines, and absence of lung pulse. Lung ultrasound rules out the diagnosis of pneumothorax more accurately than a supine anterior chest X-ray.

• Interstitial syndrome: Presence of a B-profile consisting of more than 3 B-lines on a longitudinal scanning plane. Interstitial syndrome includes pulmonary edema, interstitial lung disorders and ARDS.

• Lung consolidation: Sonographic signs are a subpleural echo-poor region or one with tissue-like echotexture. Lung ultrasound can differentiate between consolidation of pulmonary embolism, pneumonia, and atelectasis.

• Pleural effusion: A hypoechoic or anechoic space between sonoanatomical boundaries (i.e., chest wall, the diaphragm and subdiaphragmatic organs). Lung ultrasound is more accurate than chest X-ray.

• Monitoring interstitial syndrome: The number of B-lines is directly proportional to the severity of pulmonary congestion. This could be used as a monitoring parameter of severity and response to therapy. Pulmonary edema can be diagnosed, quantified, and monitored by detection of B-lines.

• Pulmonary embolism: only if it is peripheral, it can be seen sonographically by the recognition of a peripheral, triangular, and pleural based hypoechoic lesion.

Updated definition 2020:

Lung ultrasonography is a group of point of care bedside exams that can diagnose pneumothorax, interstitial syndrome, pleural effusions, and different types of pulmonary consolidations. Lung ultrasonography by a trained provider has a sensitivity and specificity over 90% as compared to CT (the “gold standard”).

There are 12 signs that can be found with critical care lung ultrasonography:

1. Bat sign: a solid landmark made by rib shadows and the pleural line (a hyperechoic line about half a centimeter below the rib line in adults representing the parietal pleura). This is normal.

2. A-line: normal lung surface associates lung sliding with horizontal repetitions of the pleural line (A-lines) which indicate normal aeration of the lung.

3. Seashore sign: putting M-mode over the pleural line reveals the seashore sign: a sandy picture indicating normal lung parenchyma and normal lung sliding.

4. Quad sign: A static sign consisting of the pleural line, shadowing from two ribs, and the lung line/visceral pleura (the deep boundary of an effusion/collection that is

roughly parallel to the pleural line). It has a high sensitivity and specificity for pleural effusion.

5. Sinusoid sign: The dynamic counterpart to the quad sign is found by putting M-mode over the lung line. It draws a sinusoidal pattern which represents respiratory variation. This also indicates a free pleural effusion with low viscosity that would be amenable to aspiration, as opposed to other less dynamic lung pathologies that may look similar to a pleural effusion on static ultrasound.

6. Fractal (shred) sign: consolidated lung tissue appears as subpleural hypoechoic regions with an irregular, or shredded, deep border (the fractal line) next to normally aerated lung. With larger consolidation, it may be too deep to be seen on ultrasound.

7. B-line: a well-defined, hyperechoic, laser-like comet tail artifact arising from the pleural line in cases of interstitial syndrome. It erases A-lines and moves with lung sliding. It corresponds with sub-pleural thickened interlobular septa.

8. Lung rocket: 3 or more B-lines between two ribs are called lung rockets and correlate with interstitial syndrome with 93% accuracy.

9. Stratosphere sign: Abolished lung sliding is found in almost all significant cases of pneumothorax with a 95% sensitivity and 100% negative predictive value. Putting M-mode over the pleural line with absent lung sliding generates the stratosphere sign and indicates total absence of motion.

10. Lung point: The point where the visceral pleura and parietal pleura separate in a pneumothorax is seen on ultrasound as the junction between sliding lung and absent sliding. It is very specific for pneumothorax but not found in all cases.

11. Lung pulse: Absent lung sliding with perception of heart activity at the pleural line and a sign of significant atelectasis. The visceral and parietal pleura are still opposed.

12. Dynamic air bronchogram: An air bronchograms is the visualization of air filled bronchi surrounded by consolidated lung parenchyma. Dynamic air bronchograms are the fluid filled alveoli and bronchi moving centrifugally with respiration. Dynamic air bronchograms move centrifugally with respiration and represent fluid inside, indicating non-retractile consolidation. This rules out resorption atelectasis (which is indicated by static air bronchograms).