Minimally Invasive Surgery

(MIS)

Principles of minimally invasive surgery (MIS)

❖ Endoscopy is a dual purpose tool (both diagnostic and therapeutic).

❖ **Terminology: -**

- **Endoscopy**: is the use of an instrument (endoscope) to visualize the interior of an organ or other area that can't be examined without surgery.
- **Ileoscopy**: endoscopy of the ileum.
- **Colonscopy**: endoscopy of the colon.
- **Protoscopy**: endoscopy of the anus and rectum e.g.: polyp resection, biopsy.
- **Bronchoscopy**: endoscopy of the trachea and bronchi.
- **Laryngeoscopy**: endoscopy of the pharynx and larynx. e.g.: laryngeal paralysis, elongated soft palate, and everted laryngeal saccules.
- **Rhinoscopy**: endoscopy of the nasal passage e.g.: biopsy, cytology, aspergillomas, and epistaxis.
- **Cystoscopy**: endoscopy of the urinary bladder e.g: ectopic ureter, stones, biopsy, and collagen injection in case of urinary incontinence.
- **Vaginoscopy**: endoscopy of the vagina.
- **Laparoscopy**: endoscopy of the peritoneal cavity. e.g.: ovariectomy, cryptorchidectomy, cystolith removal, splenectomy, gastropexy, cholecystectomy, adrenalectomy, repair of diaphragmatic hernia, liver biopsy, and renal biopsy
- **Thoracoscopy (VATs, Video-Assisted Thoracoscopic Surgery):** endoscopy of the pleural cavity. e.g.: treatment of persistent right aortic arch (PRAA), pericardial window, thoracoscopic treatment of chylothorax via thoracic duct ligation (TDL), thymoma resection, and pleural biopsy.
- **Arthroscopy**: endoscopy of the joints. e.g.: septic arthritis, medial coronoid disease (MCD), torn meniscus, rupture of cranial cruciate ligament, and osteochondritis dissicans (OCD).

❖ **Types of endoscopy: -**

- **A) Flexible endoscopy:**
  - Possess a degree of flexibility: it was designed to look or move around the corners.
  - Could make a bend of 180 degree or more.
  - Consists of handle, insertion tube (which have a working channel), and umbilical cord (which is connected to the light source).
  - Uses (Indications): examination, biopsy using biopsy forceps, cytological examination using cytology brushes, foreign body retrieving using FB retrieval forceps.
  - Immersible: handles were modified to be placed in water without risks of damage (during sterilization process).
- **B) Rigid endoscopy:**
  - Metal scope.
  - Can't be bend.
  - Lens present at the tip of the endoscope and could take various angles (0^{o}, 30^{o}, and endocameleon telescope).
  - It is placed through cannula (plastic or metal) that have a sharp or blunt tipped trocar which facilitate penetration through joint, chest and abdomen.

❖ **Red out or white out**:

Having the viewing tip of the endoscope so close to the surface of what is being examined that one can't focus on the surface (blur occur) or having debris on the viewing end of the scope.

❖ **Tri-angulation**:

Refers to visualizing the tip of biopsy or surgical instrument through the scope to perform various procedures within the joint or body cavities.

❖ **Instrumentation: -**

- Insertion of arthroscope or other instrument into the joint.
- Portals: camera portal for scope, instrument portal for power and hand tools.
- Ingress or inflow, outflow or egress.
- **Second look arthroscopy**: repeated arthroscopic examination.

❖ **Indications for endoscopic procedures in dogs and cats:**

- **Esophoscopy**: esophagitis, esophageal dilatation, foreign body removal, and biopsy.
- **Proctoscopy**: polyps, biopsy.
- **Laryngoscopy**: elongated soft palate, laryngeal paralysis, everted laryngeal saccules.
- **Cystoscopy**: diagnosis of ectopic ureter, biopsy of carcinoma, cystitis, removal of cystic stones using basket forceps or lithotripsy, and injection of collagen to control urinary incontinence.
- **Bronchoscopy**: broncho-alveolar lavage, brushing of trachea for cytology (culture).
- **Rhinoscopy**: for detection of nasal hemorrhage, discharge, fungal infection (aspergillomas).
- **Laparoscopy**: biopsy of liver, surgery, exploratory.
- **Thoracoscopy**: biopsy of pleural surface, placing chest tubes, pericardiotomy, TDL, thymus removal, lung lobectomy, pyothorax, PRAA, and diagnosis of mesothelioma.
- **Arthroscopy**: joint examination and sampling, removal of loose fragments (cartilage, bone), joint lavage in septic arthritis, removal of torn meniscus, OCD, MCD.

- Arthroscopy is better than arthrotomy due to magnification, arthroscopic fluid environment.
- 5-10 mm telescope.
- **working or operating telescope**: refers to telescopes which have working channel for biopsy forceps or other instrument.
- Laparoscope length: 30 cm
- Arthroscopes Diameter: 1.9 – 2.3 – 2.7 mm
- Small diameter scopes are associated with Less damage and greater mobility.
- Large diameter scopes are associated with greater visualization and more rigidity.
- Fluids are used in arthroscopy to maintain joint distention and remove debris and blood clot from joint.

❖ **Advantages of MIS: -**

- Reduction of pain compared to open approach (associated with lower cortisol levels in operated patients).
- Rapid return to normal activity "fast recovery".
- Reduction of tissue trauma.
- Reduction of surgical site infection (SSI), seroma, and dehiscence.
- Reduction of surgical time.
- Reduction of patient hospitalization.
- Easy to learn.
- Client acceptance.
- Greater diagnostic yield (in case of biopsy).
- Greater magnification and better image quality (magnification, light & exposure).
- Economically profitable for veterinarian.

❖ **Disadvantages: -**

- Require training.
- Risk of bleeding.
- Puncture of vital organs such as spleen
- Thermal damage
- s/c emphysema
- expensive
- omental ballooning
- fogging.
- Anesthetic and respiratory complications.

Laparoscopic equipment

- Endoscopy room: -
    - 200 – 250 square feet (for use with relative ease freedom of move around patient & for use with other modalities; VSD, C-arm fluoroscopy).
- Camera: -
    - ♦ Types: one and three chips camera.
    - ♦ Three chips camera have superior optical clarity and color reproduction.
    - ♦ Function: focus, size of field of vision, white balance, image capturing, video recording.
- Light source: -
    - ♦ Halogen or xenon.
    - ♦ Xenon better as it emits high intensity light.
    - ♦ 150 – 300 watt.
    - ♦ Care should be taken to avoid thermal burn of surgical drapes.
- Insufflator: -
    - ♦ CO_2 is used for creation of pneumoperitoneum.
    - ♦ No insufflation used in thoracoscopy in most cases (rigidity of ribs maintain the working space in the chest).
    - ♦ 3 mm Hg in Thoracoscopy could be used. Sometimes, cause cardio-respiratory depression.
    - ♦ IAP for laparoscopy in dogs 15 mm Hg and 8 mm Hg in cats.
    - ♦ Microporous filter to prevent bacteria, prevent body fluids to move in opposite direction, cross contamination, and insufflator damage.
- Advantages of CO_2: -
    - ♦ No combustion with electro-surgery devices.
    - ♦ Cheap.
    - ♦ Colorless.
    - ♦ Rapidly excreted.
    - ♦ N.B: - investigation are currently performed on the use of helium due to its minimal effect on cellular, hormonal, and immunological levels.

- Monitor: -
    - ♦ Placed in opposite sides of operating tables to keep hand eye coordination and straight view axis to decrease surgical time and iatrogenic tissue damage.
    - ♦ In case of using of one screen, it is placed on the top of tower.
- Data recording: -
    - ♦ CD, DVD, USB port e.g.: AIDA (Karl Storz recording system).
- Telescopes: -
    - ♦ Rod lens system
    - ♦ Length: - 29 cm
    - ♦ Diameter: - 3 mm, 5 mm, 10 mm.
      5 mm (for laparoscopy, Thoracoscopy), 10 mm (Endocameleon telescope).
    - ♦ Angulation: - 0^{o}, 30^{o}, endocameleon (multi-angled scope from 0 to 120^{o})
    - ♦ 30^{o} scopes (angled telescope) are ideal for arthroscopy and Thoracoscopy as it see around heart, lung, liver lobes.
- Cannula and trocars: -
    - ♦ Used for establishing access point, change instrument, maintain pressure, and prevent leakage.
    - ♦ Types:
        - Single use versus multiple use (Re-sterilized).
        - Blunt versus sharp trocar.
        - Smooth versus threaded shaft (prevent slippage).
    - ♦ Reducer caps: used for diameter reduction in case of large cannulas.
        - Disposal cannula: no reducer cap used, tissue injury avoided.
        - Non-disposal cannula: heavy, reducer cap used, dull over time and help in cost reduction.
    - ♦ Blunt cannula should be used for the creation of first port of entry to avoid organ damage.
    - ♦ SILS (Single incision laparoscopic surgery) port: placed in umbilicus, cause no visible scarring.

e.g.: - SILS (Covidien, Medtronic), TriPort (Olympus), Endocone (Karl Storz).

Advantages: - minimize number of ports used.

Disadvantages: - clashing of instruments.

- Surgical instruments: -
    - ♦ Includes: scissors, grasping forceps, biopsy forceps.
    - ♦ Instrument diameter: 5 mm.
    - ♦ Shaft is insulated; usable with monopolar electro-surgery (prevent cautery).
    - ♦ Palpating probe: used for examining and moving organs in atraumatic way.
    - ♦ Metzenbaum scissor, suture cutting scissor.
    - ♦ Babcock forceps: used for grasping of tissues
    - ♦ Biopsy cup forceps (punch, cup biopsy forceps): for biopsy collection.
    - ♦ 5 mm Right angle forceps: for dissection procedures.
    - ♦ Knot pusher: used for extracorporeal knot typing.
    - ♦ Needle holder: for intracorporeal knot typing.
    - ♦ Fan-retractor: used to push organs away from the field of view in case of cholecystectomy, adrenalectomy.
    - ♦ Endo stitch or Sils stitch for automatic intracorporeal suturing

      N.B: Sils stitch is an articulating automatic suturing instrument.
    - ♦ Retrieval bags: used for tumor or tissue extraction in case of mesothelioma, thymoma, OSA which help in minimizing port site metastasis
    - ♦ Endoscopic staplers: used for tumor excision.
- **Achieving hemostasis:**
    - ♦ Palpating probes can be used for hemostasis.
    - ♦ Hemostatic agents:
        - Gel foam (gelatin sponges)
        - Surgicel (regenerated cellulose)

          Disadvantages: tedious.
    - ♦ Hemostatic clips (hemoclips).
    - ♦ Suturing technique: -

        - Roeder knot, slip knot.
        - Pre-tied loop ligature (endoloop).
        - Needle holder.
        - Barbed suture (V Loc Suture®) (Knotless suture)
          Advantages: keeping suture line tension, no intracorporeal knot tying.
    - Monopolar and bipolar electro-surgery:
        - Great caution with monopolar electro surgery.
            - Iatrogenic injury (insulation defect).
            - Direct coupling injuries.
        - Bipolar electro surgery devices are safer in use.
            - Lower voltage
            - Current only passed between tips of bipolar instrument.
    - VSD (vessel sealing device): - crushing elastin and collagen in vessel wall to be sealed together permanently.
      e.g.: force triad (covidien), Ligasure(Enseal).
      Advantages: -
        - Decrease surgical time.
        - Safe to use in vessels up to 7 mm vessels.
        - Tissue impedance within the jaws of tipis measured to ensure safer and effective sealing.
        - Bursting pressure, thermal spread
            - 3 times systolic blood pressure.
            - 1.5 – 3.2 mm lateral thermal spread.
    - Ultrasonic waves (Sonocision): safe to use in vessels up to 3.5 mm, cordless device, battery is used for 100 times.
- Endoscopic staplers: -
    - 12 mm in diameter, 2 – 3 rows separated by cutting blade.
    - Prevent back bleeding, spillage of contaminated material in surgical field e.g: endo GIA cartridges 30, 45, 60 mm in length which used for lung lobectomy.
- **Principles of access: -**
    - For laparoscopy:

- Veress needle technique (hanging drop technique is applied to ensure entrance of abdominal cavity).
  Complications: s/c emphysema.
- Hasson technique.

♦ For thoracoscopy:
- OLV (one lung ventilation) which is achieved with the help of endobronchial blocker, selective intubation, or double lumen endobronchial tubes.
  - helpful technique in case of PRAA & Lung lobectomy.
- Thoracic insufflation (Maximum pressure used is 3 mm Hg).

Laparoscopic splenectomy (LS)

- Indications: -
  - Small to moderate splenic masses **without** hemoperitoneum.
  - Splenic torsion, trauma, neoplastic diseases (HSA), and splenic infarction.
  - Blood supply: -
    - Splenic artery from celiac artery.
    - Splenic vein gastrosplenic vein.
  - In **cats**: pancreas runs in close proximity with the splenic hilus (care should be taken to avoid pancreatic injury during the procedure).
- Patient selection: - good candidates are characterized with
  - Absence of hemoperitoneum, absence of massive splenomegaly.
  - Splenic masses smaller than 6 cm in diameter (as larger masses will hinder visualization, difficult in handling, and friable).
- Preparation: -
  - Fasting (decrease gastric dilatation).
  - Empty urinary bladder.
  - Antibiotic pre-operatively: cefazolin (22 mg/kg each 90 - 120 min)
  - Prepare abdomen for risk of conversion (from pubis to xiphoid)
  - Dorsal recumbency (with right lateral may be needed)
- Instrumentation: -
  - Sils port, blunt probe, Babcock grasping forceps, VSD, retrieval bag.
  - IAP: 12 mm Hg
  - Expose splenic hilus with probe.
  - Procedure should be started from the tail to the head of spleen.
- Complications: -
  - Hemorrhages: from trocar placement and inadequate sealing of blood vessels within the splenic hilus.
- Post-operative care: -
  - Carprofen 2 mg/kg/12hrs
  - Tramadol 2 mg/kg/12hrs
  - Discharge same day or the day after surgery.

Laparoscopic cystoscopy for cystolith removal and polyp resection

❖ Patient selection: -

- Size of stone.
- In females: transurethral cystoscopic calculus removal is preferred.

❖ Preparation: -

- Fasting 12 hrs.
- Antibiotic (cefazolin: 22 mg/kg each 90 - 120 min)
- Dorsal recumbency, wide clipping includes prepuce and vulva for urethral catheterization.

❖ Instruments: -

- Pressure bag for lavage, red rubber catheter.
- Saline to distend bladder.
- Temporary cystopexy is performed to avoid urine leakage intra-abdominally with biosyn suture material (4/0).

❖ Complications: -

- safe, effective, shorter procedural time.

❖ Post-operative care: -

- Post-operative pelvic x-ray to ensure complete removal of all stones.
- Fluid therapy for 12 - 24 hrs. post operatively for renal function
- Use every 6 months for early detection of newly formed stones.

Laparoscopic cryptorchidectomy

- Indications: -
  - Undescended testicles which is located intra-abdominally (which may lead to testicular neoplasia as seminoma and Sertoli cell tumor or testicular torsion).
  - Retained testicles in the inguinal canal not removed laparoscopically (removed with traditional surgical approach).
- Preparation: -
  - Dorsal recumbency with the back elevated 15 degrees to help in caudal abdominal visualization.
- Complications: -
  - Hemorrhage.
  - s/c emphysema.

Laparoscopic ovariectomy (OVE)

- fast, simple to perform, effective as ovariohysterectomy.
- Indication: -
  - For reproductive control.
  - The most commonly performed procedure in USA.
  - Ovaries in **dogs**: **completely** concealed in ovarian bursa and fats.
  - Ovaries in **cats**: ovarian bursa is located **laterally**.
- Contra-indication: -
  - Early pregnancy, pyometra (especially if uterine horn distended).
- Preparation: -
  - Fasting 8 - 12 hours.
  - Trans-abdominal ovarian suspension technique (using ovariectomy suspension hook) was the first mis tech. applied.
  - Tilting table 15 degree - 25 degrees to right or left sides
  - sand bags to support patient.
- Instrument: -
  - Telescope, grasping forceps, VSD, hooks, Sils port.
- Challenges: -
  - The procedure is challenging in obese animals, and in case of inadvertent splenic trauma during trocar placement.

- Complication: -
    - Puncturing of urinary bladder.
    - Bleeding from the ovarian pedicle.
    - Dropping ovary (may need conversion).
    - Burning peritoneum with VSD.
    - Seroma / hematoma at OVE hook site.
- Post-operative care: -
    - Pain medication.
    - exercise restriction.
    - E- collar.
    - Carprofen: 2.2 mg/kg per OS twice daily

Laparoscopic Adrenalectomy (LA)

- Patient selection**: Non**-invasive **moderate** size adrenal tumors.
- Indication: -
  - Adrenal tumors: adenoma, adenocarcinoma, and malignant pheochromocytoma in dogs, ferrets, and cats.
  - Possible intra operative complication is capsular rupture.
  - Clinical signs: alopecia, thin and fragile skin.
- Surgical anatomy: - (adrenal is para-renal in position)
  - **Right**: its capsule is continuous with external tunic of vena cava, **more difficult to resect**.
  - **Left**: its capsule not contact vena cava unless significantly enlarged.
  - Blood supply: - phrenico-abdominal artery/vein.
- Diagnosis: -
  - Endocrine testing: hyperadrenocortism (HAC)
  - Diagnostic imaging: - Mainly AUS & CT Angiogram.
    - to rule out vascular invasion.
    - Pheochromocytoma is invasive in 55% of cases.
    - Adrenocortical tumors are invasive in 2-21% of cases.
    - **peri-renal fat in cats more than dogs** (more challenging in cats).
    - **Cranial pole lesions are easier to dissect** due to less relations with renal artery and vein.
    - In **pheochromocytoma**: - alpha adrenergic blocker as **phenoxybenzamine** (1-1.5 mg/kg PO) for 2 weeks before surgery till normotensive, help in maintain vascular resistance, cardiac rhythm.
- Patient preparation: -
  - Position: -
    - Lateral recumbency: -
      - Clipping from mid thorax cranially till hind limb caudally.
      - Clipping from transverse spinous process proximally till mid abdominal area on both sides.
      - For risks of conversion to ventral midline celiotomy.

- Sternal recumbency: -
    - For bilateral 360-degree clip.

Port Placement:

A- <u>In case of multi-port approach</u>: the scope port is placed 3-5 cm lateral to umbilicus and the other instrument port are placed 5-8 cm apart on both sides of the first (scope) port.

B- <u>In case of SILS</u>: Sils port is placed 3-5 cm lateral to umbilicus.

❖ Instruments: -

- 30-degree scope.
- Specimen retrieval bag.
- Babcock forceps, right angle dissection forceps.
- Ligasure.
- J-hook electro surgery for dissection around adrenal tumor (care in use due to higher temperature, greater lateral thermal spread, caution near CVC and renal vein).
- Suction devices to clear tissue planes (challenge from hemorrhage and fat).
- Phrenico abdominal artery and vein could be used as **handle** after ligation to avoid capsular rupture.
- Check for hemorrhage before de-sufflation.
- **<u>More challenge in cats: -</u>**
    - Use 3mm instruments (pediatric set).
    - Mass (aldosterone, cortisol, or progesterone secreting masses) causes body wall fragility which lead to chronic Loss of pneumoperitoneum which decrease working space.
    - Gland is hidden in large perirenal fat pad.

❖ Complications: -

- Hemorrhage: -
    - From PA and neovascularization (**controllable**).
    - From Cava, renal vein and artery (**convert** to celiotomy).
- Capsular rupture: not known if clinically important or not so, long term studies needed, recurrences histopathology.
- Inadvertent injury to kidney, spleen, pancreas, and diaphragm penetration (pneumothorax on right sided).

- Pancreatitis: fatal post-operative complication.

❖ Post-operative care: -

- Hydromorphone 0.1 mg/kg IV/q 4 hours.
- Tramadol at discharge 2mg/kg PO 3 times a day for 3-5 days.
- Carprofen 2.2 mg/kg PO 3 times a day for 3-7 days.
- Hospitalization for 48 hours.

Laparoscopic cholecystectomy (LC)

❖ Indication: -

- **uncomplicated** G.B mucocele / with **no evidence** of extra-hepatic bile duct **obstruction**.
- Cholelithiasis uncommon in dogs.

❖ **Contra-indication: -**

- Bile peritonitis (GB Rupture).
- Extra-hepatic bile duct obstruction (for flushing of bile from the common duct is performed).

❖ Anatomy: -

- GB located in hepatic fossa between right medial and quadrate lobes of liver.
- Cystic artery which is a branch from hepatic artery (ligated with bile duct during the procedure).

❖ Diagnosis: -

- Increased hepatic enzymes and increase total bilirubin.
- AUS: wall thickness, inflammation, degree of filling lumen with mucous (**kiwi-gallbladder** appearance in case of gall bladder mucocele) (**GBM**).

❖ Patient preparation: -

- Clip 5 cm cranial to xiphoid till prepuce.
- Laterally, till dorsal third.
- Dorsal recumbency: -
    - 4 – port technique (scope port at umbilicus, first and second instrumental port on both sides of scope port, third instrumental port at the costal arch on the **left** side for placing of fan retractor).

- Sils port technique (Port is place at sub umbilical position)

❖ Instruments: -

- Metzenbaum scissors.
- Babcock forceps.
- Right angle forceps.
- Fan Retractor.
- Ligasure.
- Specimen retrieval Bag.
- Biopsy forceps.
- No significant difference between endoclip and VSD in failure pressure.

❖ Complications: -

- Perforation of G.B during dissection from hepatic fossa.
- Leakage from cystic duct stump after LC (secure closure needed)
- Hemorrhage from hepatic fossa.

❖ Post-operative care: -

- Tramadol
- Oxymorphone 0.05 mg/kg/4hrs for 2 days.
- Biochemical screen after 48 hrs. then 2 weeks (reduction in T. Bilirubin).

Laparoscopic and laparoscopic-assisted gastropexy

❖ Indication: -

♦ Done as a preventive surgery to prevent GDV (**Prophylactic gastropexy**).

♦ 60000 dog annually (German shepherd, great Dane, Irish setter) suffer from GDV.

❖ Pathophysiology: -

♦ Gastric dilatation will lead to compression of portal vein and cava → hypotension → gastric necrosis and cardiogenic shock → death.

♦ Treatment without gastropexy ---- recurrence rate is 50%.

❖ Causes of GDV: -

♦ Increase age.

- ♦ Increase thoracic depth to width ratio (Deep chested dogs).
- ♦ Male more than females.
- ♦ Gastric Foreign body, history of splenectomy, stress.
- ♦ Once daily feeding, elevated bowel, aerophagia.

❖ Patient preparation: -

- ♦ Fasting 12 hours.
- ♦ Xiphoid to pubic brim clipping.
- ♦ Cefazolin 22mg/kg every 90 minutes.

❖ Techniques: -

- ♦ **Lap-assisted gastropexy by Dr. Rawlings (two ports): -**
  - Dorsal recumbency.
  - First port placed at Lateral margin of Rectus abdominus 3-5 cm caudal to last rib (13^{th}).
  - Second port (sub-umbilical port).
  - Gastropexy Location: -
    - **Pyloric Antrum** (Midway between greater and lesser curvature of stomach 5-7 cm oral to the pylorus.
    - Avoid twisting of stomach during surgery.
    - Seromuscular layer (Flap) is sutured to the transverse abdominal muscle with V Loc Suture.
- ♦ **Intra-corporeal gastropexy by Dr. Mayhew in 2009: -**
  - Dorsal recumbency.
  - Seromuscular Incision as well as transverse abdominal muscle incision are 3-5cm long.
  - Two techniques exist:
    1- Three port tech.: - scope port is sub-umbilical, second port is 4 cm caudal to xiphoid, third port is in the midway between first and second ports.
    2- Sils tech.: Sils port is placed subumbilically, additional port is placed 2-3 cm lateral to the rectus abdominus and 5 cm caudal to the 13^{th} rib.
  - Advantages: -
    - Reduce tissue trauma and seroma formation.

❖ Complications: -

- ♦ Stomach perforation.

- Vomiting, regurgitation.
- Seroma formation (for lap. Assisted gastropexy).

❖ Post-operative care: - (one night of hospitalization)

- Pain control (tramadol).
- Gradual food (small meals 8-12 hrs. later).
- E-collar, restriction of activity.
- Decrease future bloat via offering several meals small versus once daily feeding, reducing speed of eating, limit stresses, raised bowel feeding.

Diaphragmatic Herniorrhaphy

❖ Indication: -

- **Acute** and **cardiopulmonary stable** cases of diaphragmatic hernia (**No adhesions**).
- Low pressure (3mmHg) could be used.
- Barbed suture is advantageous in treatment of diaphragmatic hernia (V-loc).

❖ Anatomy: -

- Diaphragm: -
  - **A) Central tendinous part**: triangular in shape, have the caval foramen. Constitute 21% of the diaphragm.
  - **B) Muscular part**: -
    - **Lumbar**: consists of right and left crus (Right > left). Have aortic hiatus via which aorta, azygos vein, and thoracic duct pass. Also, have esophageal hiatus via which the vagal nerve trunk and esophagus pass.
    - **Costal**.
- Innervation: - phrenic nerve (comes from 5^{th} -7^{th} cervical nerves)
  - Causes: Traumatic origins, hit by car(HBC).
  - Dyspnea is major clinical sign.

❖ Diagnosis: -

- Chest x-ray (diagnostic): - Pleural effusion, herniated organs as liver, Omentum, and small intestine.

- ♦ The hernia occurs mostly in costal muscle, central tendinous part less often.

❖ Patient preparation: -

- ♦ Liver challenging to reduce (manipulation and grasping may cause hemorrhage).
- ♦ Small intestine easily reduced.
- ♦ Dual thoracoscopic and laparoscopic approaches may be advantageous for hernia reduction.
- ♦ It necessary to explore each case with laparoscopy then take the decision.
- ♦ If reduction or repair is too difficult, conversion to open approach is a must.

❖ Port Placement (three cannula procedure): scope port is placed caudal to the umbilicus. The other instrumental ports placed equi distant on both sides of the scope port

❖ Position: -

- ♦ Dorsal recumbency in **Reverse Trendelenburg position** (gravity).
- ♦ Patient placed on ventilator during procedures.

❖ Instruments: -

- ♦ 3 cannula procedure.
- ♦ Fine atraumatic grasping forceps is used for SI, GB.
- ♦ 3mmHg for pulmonary compliance and venous return.
- ♦ Blunt palpating probe for liver.
- ♦ N.B: - before starting closure of diaphragm, chest tube is inserted in an intercostal space with laparoscopic visualization across diaphragm.
- ♦ Knotless suture (V Loc suture) is used with needle drivers or endostitch.
- ♦ Suturing process should be **started dorsally** and continued towards the ventral aspect of diaphragm in a simple continuous manner.
- ♦ At the end of suturing line, 2 stitches were taken in the opposite direction with 2/0 (V-loc 180).
- ♦ Pay attention for Caudal vena cava.

- Evacuate pleural space through thoracostomy tube to restore the negative pressure within the chest.

❖ After care: -

- Pleural space is evacuated each 4-6 hours, if no air or minimal fluid production, remove tube.
- Analgesia through I/V or tube in chest (1.5 mg/kg) lido/bupivacaine mixture.
- Blood gas analysis every 4-6 hrs. post-operative to make sure that patient is ventilating adequately, atelectasis is resolving.
- if patient is hypoxemic, supplemental oxygen is provided until lung function improve.

Laparoscopic liver biopsy (LLB)

❖ Quick, safe, and minimally invasive method for obtaining samples of diagnostic quality in dogs and cats.

❖ Very low complication rate even in patients with coagulopathy and ascites.

❖ Indications: -

- Elevated liver enzymes.
- Investigation of US identified lesions.
- Abnormal liver size.
- Staging of neoplastic disease.

❖ Advantages: -

- Liver biopsy site can be selected under direct laparoscopic visualization.
- Hemorrhage can be monitored and addressed.
- Quick.

❖ Anatomy: -

- Six lobes (caudate divided into caudate and papillary processes).
- Blood supply: - Liver have a unique blood supply
  - Portal vein: provide 80% of blood volume, 50% of O_2 supply.
  - Hepatic artery (branch of celiac artery).

❖ Diagnosis: -

- ♦ Serum biochemistry, CBC.
- ♦ Abdominal X-Ray: loss of serosal details and free abdominal fluids.
- ♦ AUS: evaluate liver parenchyma, size.
- ♦ N.B: - due to potential for hemorrhage from liver biopsy in hepatic dysfunction, PT and PTT should be done.

❖ Contra-indication: -

- ♦ Thrombocytopenia (< 80000 plate/ml).
- ♦ Marked prolongation of coagulation time.

❖ Patient preparation: -

- ♦ Clipping: 5 cm cranial to xiphoid process till prepuce. laterally to dorsal half of abdominal wall.
- ♦ Dorsal recumbency.
- ♦ A two port or single port (SILS) technique (scope port is placed in subumbilical position and the instrumental port placed mid-way between camera port and xiphoid process.
- ♦ Instruments: -
  - Blunt palpating probes.
  - Cup or punch biopsy forceps.
  - Ligasure, endoloop.
  - Gel-foam for hemostasis.
- ♦ Keep biopsy forceps closed for 30 second then twisted and gently pulled. blunt probe pressed into biopsy site to promote hemostasis.
- ♦ If lesions are not in the periphery of the liver lobe, the biopsy forceps is inserted with the jaws opened.

❖ Complication: -

- ♦ Safe procedure with very low complication rate even in coagulopathy, thrombocytopenia, ascites due to hepatic biliary dysfunction.
- ♦ Tramadol 2mg/kg PO every 8 hours.
- ♦ **No NSAIDs** (due to hepatic dysfunction).
- ♦ Discharged same day.

Laparoscopic Renal Biopsy

- Indication: -
    - Persistent, progressive and non-responsive proteinuria.
    - Renal mass.
    - Acute, severe kidney injury.
- Contra-indication for renal biopsy: -
    - Hydronephrosis.
    - CKD IV, (end stage renal disease).
    - Uncontrolled pyelonephritis.
    - Cystic renal disease.
    - Why laparoscopy is preferred for renal biopsy?!
        - FNA: may get mainly medullary tissue (germinal).
        - Hemorrhage is monitored.
- Patient preparation: - **major risk is hemorrhage**
    - PT, platelet count.
    - AUS to evaluate kidney.
    - Clipping ventral abdomen.
    - Position: -
        - In Left kidney biopsy (more caudal): patient is positioned in right lateral recumbency.
        - In Right kidney biopsy: patient is positioned in left lateral recumbency.
    - Port Placement: - Scope port is placed 2 cm caudal and 2 cm lateral to the umbilicus. The second (instrumental port is placed 4 cm lateral to the scope port.
    - Blunt probe to retract kidney or bowel or omentum or apply direct pressure to biopsy site.
    - **Tru-cut needle** 14-16 gauge is used to obtain the renal biopsy.
    - Technique: -
        - **Avoid center of kidney** (collection from cranial or caudal pole).
        - Be **Perpendicular** to longitudinal axis of kidney.
        - **Avoid medullary tissue** to avoid hemorrhage and urine leakage, delivering non-diagnostic samples.

- needle is placed adjacent or immediately under the renal capsule.
- If hemorrhage occur: -
    - Pressure with blunt probe.
    - Gel foam is used as hemostatic agent.
- **Five glomeruli** needed for adequate interpretation.

❖ Complications: -

- Hemorrhage.
- Peri-renal hematoma.
- Fibrosis.

❖ Post-operative care: -

- Fluid therapy to minimize the risk of blood clot formation.
- Hospitalizing overnight.
- Before dismissal, AUS is done for recheck of biopsy site (to rule out hematoma formation).

Thoracoscopy for Small Animals

- Patient positioning: -
    - Dorsal recumbency: in case of median sternotomy.
    - Lateral recumbency: in case of intercostal thoracotomy (IC).
    - Sternal recumbency: TDL.
- Approach: -
    - Sub-xiphoid approach.
    - Intercostal approach.
    - Clipping: -
        - Entire lateral thorax and cranial half of abdomen.
        - Limb were tied.
        - Mid neck till umbilicus caudally.
    - No gas insufflation used as ribs maintain a rigid frame which maintain working space, so no need to maintain a tight seal around port sites as for laparoscopy.
    - **Obtain access for Thoracoscopy is less problematic than laparoscopy.**
- Access: -
    - Traditional **open technique**: similar to Hasson technique.
    - **Optical entry**: visualizing penetration with telescope as cannula placement occurring.
    - Thoracoport: - **don't have a value** that prevent gas leakage.
- Sub xiphoid approach: -
    - Tech: -
        - Cannula pushed in 45^{O} degree to ventral mid line to ensure clean passage through the most ventral aspect of diaphragm and hemithorax of choice.
    - Complications: -
        - Entering abdominal cavity: you will see liver lobe and caudal aspect of diaphragm.
        - Enter pleural reflection.
    - Cannula size 6.5 cm length (range: 8-10cm) for both dogs and cats.

❖ Sub xiphoid approach: -

- Selection which ICS and be more dorsal or more ventral is dictated by procedure to be done.
- Use **small cannula** diameter to help maximal angulation of cannula.
- Complications: -
  - Injury, **hemorrhage from IC neurovascular bundle** (before, during, after) inspect site after cannula removal.
    If Bleeding occur: VSD, hemoclips, so close to periosteum of ribs.
  - **Injury to lung parenchyma** especially in cases of adhesion of lung with thoracic wall in case of chronic pleural effusion.

❖ Post-operative complication at thoracoscopic port sites: -

- Port site infection.
- Seroma.
- Port site metastasis.

❖ Video assisted thoracic surgery (VATS) = Thoracoscopy: -

- Indication: -
  - Hemodynamically stable patient.
  - Have a disease can be safely and effectively treated with VATS.
  - Owner knows risks and potentials for conversion (**subjectivity** exist on defining patient as candidate).
- How to avoid complications: -
  - Pre-operative assessment (30% HCT is needed at least).
  - Patient preparation and conversion (Should be prepared).
  - Antibiotic prophylaxis: cefazolin 22mg/kg every 90 min IV.
  - Exposure and working space (Increase working space).
- Pneumothorax cause retraction of pulmonary parenchyma from wall leading to limit pulmonary expansion→ hypoventilation and hypoxemia → further impairment by pleural CO_2 insufflation and OLV.
- **PEEP** (positive end expiratory pressure ventilation); 2.5 or 5cm H_2O will minimize effect.

❖ How to increase working space?!

- Patient positioning and tilting (lateral oblique, 20^{o} degree)
- CO_2 insufflation (3mmHg) not well tolerated even in clinically normal dog
- decrease tidal volume and increase Respiratory rate.
- OLV.
- Using Fan retractor, blunt probe: care for lung.
- OLV (one Lung Ventilation): - achieved via
  - Selective bronchial intubation.
  - Endobronchial blocker.
  - Double-lumen endobronchial tube.
  - Limited to surgical dissection, both surgeon and anesthesiologist should work together.

❖ Complications: -

- Port placement:
  - Inappropriate port placement may lead to inability to complete surgery.
  - Hemorrhage of IC arteries and veins.
  - Seroma, infection, metastasis.
- Pericardial:
  - Phrenic nerve transection during sub-phrenic pericardectomy (leading to paralysis of diaphragm).
  - Hemorrhage.
- Vascular:
  - PRAA hemorrhage if patent Ligamentum arteriosum (LA).
  - Thymoma removal (< 5cm) cr.v.c, brachycephalic A, internal thoracic A.
  - Thoracic duct (TD) run on dorsolateral right side of aorta in caudal thorax.
- Pulmonary:
  - Lung: -
    - Occupy large volume of pleural space.
    - Under cyclic motion.
    - Easily injured.

- Hemorrhage, inability to access specific lung lobe, large size pulmonary tumor.

❖ Before closure, check for: -
- Hemorrhage.
- Air leakage (Persistent pneumothorax).
- Thoracostomy tube to create negative pleural pressure and monitoring of possible post-operative complication as pyothorax, pneumothorax, and hemorrhage.

❖ Advantages: -
- Decrease Post-operative pain.
- Rapid Improvement post-operatively.
- Decrease pneumonia, sepsis, death.

❖ N.B: -
- Thoracoport are 5.5 mm, 11.5mm in diameter and 6.5 cm in length.
- Ventilation perfusion mismatch in OLV is anticipated but has no substantial / detrimental effect on oxygen delivery.

Thoracoscopic mediastinal mass removal

(Thymoma resection)

❖ The **tumor size** and the presence of **vascular invasion** are major factors to evaluate when considering the use of Thoracoscopy for resection.

❖ Surgical anatomy: -
- Mediastinum: it's the space between right and left pleural sacs, that enclose number of organs, vessels and nerves.
- Cranial mediastinum contains: -
  - Esophagus.
  - Trachea.
  - Phrenic nerves diverge on dorsolateral aspect of pericardium.
  - Vagus nerves (follow course of esophagus)
  - Left subclavian, brachiocephalic arteries.

        - Cranial vena cava (cr.v.c).
        - Thymus.
        - Thoracic duct (TD)
    - **Internal thoracic arteries**: arises from subclavian arteries, and give branches: thymus, pericardium, and bronchi.

❖ Diagnostics: -

- CBC, serum biochemistry (**Ionized Ca^{++}**), PT.
- Chest x-ray: 3 view (for size of mass, metastasis, comorbidities as mega esophagus and aspiration pneumonia).
- **CE-CT** (Contrast enhanced computed tomography): provide important information about **vascular invasion** mainly with **internal thoracic arteries**.

❖ Patient selection: -

- **A)** Tumor characteristics:
    - Vascular invasion.
    - Not clearly capsulated.
    - Have dense adhesion with thoracic structure, i.e., not good candidate for thoracoscopic removal.
- **B)** Tumor size:
    - 8 cm in dogs 30 kg.
    - 5 cm in dogs 15-30 kg.

❖ Patient preparation: -

- Positioning **dorsal recumbency**, **sub xiphoid approach**.
- Clipping: whole thoracic area, abdomen partially clipped.

❖ Instruments: -

- 30-degree telescope for confined space.
- Blunt probe.
- VSD.
- Suction devices; remove blood, fat, fluid.
- Specimen retrieval bag.
- Right angle forceps.
- J-hook, L-hook electro surgery to dissect near vital structures.
- Ports: 3 or 4 cannula.
- Scope port is placed in sub xiphoid position, other instrumental ports are placed in the **6^{th} ICS** in both right and left side.

- Care for **phrenic nerve** (grasp mediastinum, moving from side to side, blunt dissection).
- Care **not to perforate capsule**, tumor rupture.
- Sternal lymph node sampling, thoracostomy tube placing via a separate hole.
- Closing at least 2 layers (intercostal muscles, serrates Ventralis muscles).

❖ Post-operative care: -

- Thoracostomy tube: monitoring of air and fluid drainage.
- Pain management:
  - Opioids I/V then oral pain medication.
  - Local analgesic via thoracostomy tube.
  - Intercostal nerve block.
  - E-collar + monitoring of port sites.
- Long term monitoring → blood work for **<u>paraneoplastic disease</u>**: myasthenia gravis, mega esophagus, hypercalcemia.
- Thoracic radiography.

❖ Complications: -

- Conversion to open approach: in case of severe adhesion or metastatic disease diagnosis.
- Aspiration pneumonia.
- Injury to vital structure: as phrenic, cr.v.c., internal thoracic, bleeding.
- Port site metastasis or local seeding: if tumor rupture or friable.

<u>Thoracoscopic pericardial window</u>

<u>Sub-total pericardectomy</u>

❖ Indicated for decompression of pericardium in case of pericardial effusion.

❖ Pericardial effusion:

- 7% of dogs suffer from pericardial effusion due to idiopathic pericarditis, neoplasia (HSA, mesothelioma, and chemodectoma).

- Cats are affected due to feline infectious peritonitis, lymphosarcoma.

❖ **Idiopathic Pericardial effusion:** sterile, hemorrhagic effusion in pericardial space with **no evidence** of infection, trauma, neoplasia or cardiac disease e.g.: German shepherd, Great Dane, saint Bernard dogs (male > female).

❖ Chemodectoma = heart base tumor = aortic body tumors.

❖ Aim or indication: -

- Establish a permanent drainage for patient with Pericardial effusion (constructive pericarditis).
- Additional surgery for treatment of chylothorax.

- MST (median survival time) higher in patients that performed window.

❖ Anatomy: -

- Pericardium protects heart from infection, prevent its dislocation:
  - A) Parietal: outer fibrous membrane.
  - B) Visceral: epicardium, serous membrane.
- Pericardial cavity: interposed between these two layers.
- Pericardial effusion: accumulation of fluids in Pericardial space.
- Parietal pericardium has blood supply from internal thoracic, aorta, superficial branch of coronary.

❖ Diagnosis: -

- To rule out tumor-associated Pericardial effusion.
- Echocardiography, CT angiogram.

❖ Patient selection: -

- **Only hemodynamically stable patients**.
- Creation of **4X4 cm pericardial window** to palliate clinical signs.

❖ Preparation and positioning: -

- **Dorsal recumbency, sub xiphoid approach.**
- lateral recumbency (when combined with thoracic duct surgery).
- Clipping both sides of chest from sternum to dorsal 1/3 of rib cage, also adequate region of cranial abdomen caudal to xiphoid.
- Dorsal recumbency (sub xiphoid approach): scope port is placed trans-diaphragmatically, other ports are placed at **6th ICS** on each side + additional cannula on **left 4th for suction**.

- Creation of working space by open pneumothorax, OLV, or 3 mmHg pressure.

❖ Instruments: -

- Angled 30 degree 5 mm telescope (2.7 mm in cats)
- Graspers, scissors, probes.
- Suction/irrigation devices
- Specimen retrieval device.
- Endo GIA.
- VSD.

❖ Technique: -

- **A) Sub-phrenic pericardectomy**: Pericardium is resected up to **1 cm ventral to phrenic nerve** (neoplasia).
- **B) Pericardial Window**: **4-5 cm window in diameter** is removed. (in case of Inflammatory disease, idiopathic pericarditis).
- Greater visibility in sub phrenic pericardectomy of intra pericardial structures such as right and left auricles, right atrium, pulmonary artery.

❖ Recommendation: remove as much pericardium as possible with **care to phrenic nerve**.

- Resect ventral mediastinum by VSD.
- Tenting of pericardium by Babcock forceps.
- Some prefer to start at apex of heart.
- Retrieve pericardium.
- Pericardioscopy.
- Chest tube placement.

❖ Complications: -

- Pericardial grasping slip away.
- Lack of visualization: visualization is better in deep chested dogs than brachycephalic dogs (Flat- faced dogs) as English and French bulldogs.
- Bleeding from ventral mediastinum.
- Myocardial puncture leading to bleeding.
- Phrenic nerve injury: when pericardium is very thick and inflamed, nerve can't be recognized.

- Port site metastasis: as in case of mesothelioma.

❖ Post-operative care: -

- Hospitalization 24-48 hours.

Thoracoscopic treatment of chylothorax

Thoracic Duct Ligation (TDL)

❖ Causes of chylothorax are not completely understood.

❖ Chylothorax:

- 1) Primary: idiopathic.
- 2) Secondary: cause may be mass obstruction of great vein as thymoma and lymphosarcoma, cardiac disease as cardiac myopathy and heart base tumor, diaphragmatic hernia, dirofilariasis, congenital lymphatic anomalies).

❖ Pathophysiology: -

- Chyle is delivered to venous circulation via TD → obstruction in TD or lymphatic venous anastomosis → increase hydrostatic pressure→ chyle leakage → if chronic, **fibrosing pleuritis** which is **more common in cats**.

❖ Anatomy: -

- Drainage of caudal half of body + viscera → collected in cisterna chyli (sac like structure) → Pass diaphragm → converted to TD → dorsal to aorta (**Thoracic duct is right in dog & left in cats**) and Ventral to azygous vein → TD anastomosis with venous system at left jugular, left subclavian, azygous veins.

❖ Diagnosis: -

- Blood CBC, biochemical (extensive and expensive).
- Heart worm.
- Abdominal and thoracic x-ray.
- Echocardiography to rule out cardiac conditions.
- CT-Lymphangiogram: to evaluate pulmonary parenchyma, number and location of TD branches via **popliteal L.N. injection** with **dye as methylene blue (MB) or indocyanine green (ICG)**.

- Fluid (Chest): diagnostic and therapeutic → for cytology, biochemical and culture (aero, an aerobic and fungi). (**TG of fluid > TG of serum**).
- When Triglyceride concentration in chest fluids is **higher** than its value in serum is diagnostic for chylous effusion (Chylothorax).

❖ Medical management: -
- Low fat diet: increase fluid absorption.
- **Rutin: 50-100 mg/kg orally every 8 hours**.
- Failure in response to medical treatment up to 4 weeks → candidate for surgery.

❖ Prognostic factor: -
- Debatable 50-100%
- Idiopathic (85% success rate) > secondary (treat primary cause).
- Continuous chylous effusion can't be predicted before or after surgery.
- **Chronic chylous effusion** → higher risk for **lung lobe torsion**.

❖ Patient preparation: -
- Fasting 12 hours before.
- Position: -
  - **Lateral recumbency**.
  - **Sternal recumbency** (helpful if multiple branches bilaterally symmetrical).
  - TD in **dog** (right) → **Left Lateral** recumbency.
  - TD in **cat** (left) → **Right Lateral** recumbency
- Clipping entire thorax and side of abdomen.
- First port at dorsal 1/3 of **8th ICS**, two ports in **9th ,10th ICS** dorsally.

❖ Instrument: -
- Grasping forceps, dissecting forceps, scissors.
- VSD, endoclip.
- Dyes: MB, ICG, saline.
- **Near Infra-Red (NIFR)** telescope.

❖ TD, CC have thin fragile margins, difficult to identify:
- Color last for 60 minutes.

- For Ligation, **Mesenteric L.N** is injected with **M.B (1:1)** → end point is reached after TDL is **pressurization with M.B** + ceased after TDL ligation site.

❖ Cisterna chyli ablation (CCA) via paracostal laparotomy.

❖ Pericardectomy (**Swan-Ganz catheter**) → pericardium is submitted to histological examination, culture, sensitivity testing.

❖ Swan-Ganz catheter is used to measure intra-cardiac pressure in different cardiac chambers for diagnosis of constrictive pericarditis to decide to do pericardial window or not.

- Thoracostomy tube placement (for air removal from the chest) + **pluroport placement** (to provide permanent drainage of chyle in a less traumatic way than chest tapping), closing of Thoracoscopy and laparoscopy port sites.

❖ Complication and prognosis: -

- 1) **General**: hemorrhage, inadvertent injury to pulmonary parenchyma, pneumothorax.
- 2) **Specific**:
  - TD laceration and chyle leakage.
  - Pericardectomy complications.

❖ Post-operative care: -

- Thoracostomy tube aspiration regularly.
- Intra-pleural local anesthetic (Lidocaine 1.5 mg/kg every 8 hours).
- Fentanyl 5 µg/kg/hrs. as CRI.
- Hospitalization depends on patient response to surgery (2-5 days).
- Owner can recognize ventilatory compromise in their pet.
  Regular follow up (1,3,6 months → then 1 year → 2 year).

Thoracoscopic treatment of vascular ring anomalies

Thoracoscopic treatment of Persistent Right Aortic Arch (PRAA)

❖ Indication: - treatment of PRAA with left ligamentum arteriosum.

❖ Susceptible Breeds: German shepherd, Irish setter, Boston terriers.

❖ Presentation: - on young animals transitioned from liquid to solid food, regurgitation and dropping of food is the main clinical presentation.

❖ Patient selection: -

- Esophageal diameter and motility rarely become completely normal after surgery (**palliative not curative surgery**).
- Semi-liquid food and upright feeding may be necessary for long period.
- Prognostic factors: -
  - Severe dilatation of cranial esophagus.
  - Dilation and hypomotility of esophagus caudal to VRA → leads to vagal injury.
  - Timing of surgical interference.

❖ Contra-indication: **double aortic arch** (as associated with respiratory signs) & **aberrant subclavian artery**.

❖ Diagnosis: -
- Regurgitation postprandially after weaning (solid food).
- Affected puppies are small compared to their litter-mates.
- X-ray: - dilation of esophagus at base of heart (plain/barium sulphate meal).
- Esophagoscopy, pulsation against right wall of esophagus.
- CT angiogram.

❖ Patient preparation: - (care for aspiration pneumonia)
- Position:
  - **Right lateral recumbency** (with slightly oblique position) using sand bag dorsally.
- OLV, decrease tidal volume, fan retractor for **left cranial lung lobe**.
- Port placement: - **dorsal 1/3 of left 8th or 9th ICS**.
- Instrument should be perpendicular to axis of Ligamentum Arteriosum to facilitates dissection.

❖ Instruments: -
- 30-degree telescope for visualization of LA.
- 4 cannulas.
- Palpation probe and stomach tube.
- Hemoclip or VSD.
- Right angle forceps.

❖ **Care for**: -
- Vagus and phrenic nerves, wall of esophagus, patency of LA.

- Remaining fibrous bands limiting expansion of esophagus.
- **Left cranial lung lobe** (**no** twisting on its hilus).

❖ Post-operative care: -

- Advantages: -
  - Thoracic cavity not fully exposed → minimal hypothermia.
  - Less painful → rapid recover of respiratory function.
- Pain control: -
  - Lido/bupivacaine: 1.5 mg/kg intra pleuraly injection via chest tube every 6 hours.
- Remove chest tube after 6-8 hrs. post-operative if no air or fluid produced.
- Management practice: includes upright feeding, semi-liquid diets.

❖ Complications: -

- Injury to esophageal wall (serosa) →clear, glistening fluid pouring out from esophagus.
- Hemorrhage from patent/perfused ligamentum arteriosum → conversion IC thoracotomy.
- Leaving remaining fibrous bands.
- Injury to lung lobe or twisting on its hilus.
- Aspiration pneumonia.

Equine Minimally invasive surgery

A) Equine Laparoscopy

1- Colopexy

- Large colon displacement and volvulus are common and their recurrence rate after correction is 15 %.

❖ Patient Selection: -

- Patients with **second** large colon displacement and/or volvulus should be considered as a candidate for laparoscopic colopexy.

❖ Pre-operative management: -

- Physical examination.
- Ultrasonic examination
- Fasting enhances intra- abdominal visibility and colonic manipulation.

❖ Surgical anatomy: -

- Colon course in equine starts with right ventral → left ventral → left dorsal →right dorsal → transverse colon →descending colon (small colon).
- Caecum and ascending colon have bands of smooth muscle **(Teniae)** which cause theses organs to form pouches called **Haustrae**.

❖ Surgical techniques: -

- Anesthesia: general anesthesia.
- Patient position: **dorsal recumbency**.
- 4 ports used:
    - A- Camera port: 1 cm skin incision at the umbilicus.
    - B- First instrumental port: 1 cm skin incision, 25 cm cranial to umbilicus and 15 cm left to ventral midline.
    - C- 25 cm skin incision is made starting 5 cm caudal to the first instrument port and parallel to ventral midline in caudal direction.
    - D- Second instrumental port: 5 cm caudal and 2 cm axial to the long skin incision.
    - E- Third instrumental port: 8 cm axial to the second port.
- IAP: 15 mm Hg.
- Cannula: 10 – 12 mm
- Telescope: 10 mm, 30^{o} laparoscope.
- The **left ventral colon** is identified and the lateral taenia of it is grasped with Babcock grasping forceps that is placed through the cranial instrumental port.
- Grasped colon is elevated towards the ventral abdominal wall and sutured using **size 1 monofilament maxon with large half curved needle** due to relatively long-term retention.
- A bite of tenia is taken and passed out of the abdomen and tied outside abdomen.
- The process is continued until **20 cm pexy** has been established.
- Abdomen was then deflated and skin closure was done in anatomic fashion.

❖ Post-operative care:
- NSAIDs are given for 3 days post-operative.
- Exercise restriction for 30 days.

❖ Complication of open colopexy:
- Weight loss
- Catastrophic failure of colon at pexy site (rupture).
- Entero-cutaneous fistula (due to incision infection and herniation).

❖ Complication of laparoscopic colopexy:
- Intermittent colic may be experienced with the first 2-4 weeks post-operatively which respond to analgesic drugs.

❖ Conversion to open colopexy:
- If correct location of colopexy is not visually apparent.

❖ Benefits of laparoscopic colopexy:
- Elective procedure: allow surgeon to avoid compromised colon during open surgery. Usually performed **one month** after the open surgical correction. It is preferred to be done after the **first** displacement in case of broodmares and after the **second** displacement in case of performance horses.
- Earlier return to function.
- Reducing incisional morbidity.

2- Ovariectomy for removal of large pathologic ovaries in mares

- Ovariectomy Could be performed in **both ventral & standing lateral approaches** for removal of both normal & pathologic ovaries.

❖ Causes for enlarged ovaries:
- granulosa cell tumor (GCTs): characterized by stallion like behavior, aggressiveness, disruption of estrus cycle (anestrus, prolonged, continuous estrus).
- Teratomas.
- ovarian cysts.
- ovarian hematoma.

❖ Indications: -

- mare with enlarged ovaries (granulosa cell tumor (GCTs), Teratomas, ovarian cysts, ovarian hematoma).
- in this procedure flank incision not exceed 10 cm.

❖ Contraindications & conversion: -

- **No contraindication** for standing laparoscopic ovariectomy.
- conversion to ventral mid line celiotomy under general anesthesia in case of **extensive adhesions** to mesentery, small intestine, other surrounding structures.

❖ Instruments: -

- 0 or 30^{o} (angled) degree laparoscope.
- 3 X 10 mm in diameter, 20 cm long trocar-cannula unit.
- laparoscopic injection needle.
- grasping forceps.
- retrieval bag.
- Ligasure.

❖ Patient Preparation: -

- physical examination.
- CBC, serum biochemistry.
- rectal examination.
- rectal ultrasound examination: to assess size & location, composition of ovary and presence of adhesion between ovary & surrounding tissue.
- left flank aseptically prepared
- food withheld for 12 hours preoperative with free access to water
- procaine penicillin (22,000 IU/kg I/M) & phenyl butazone (4.4 mg/kg IV).
- tail is bandaged & tied to doors of stocks
- horizontal bars of stocks are low to enable free movement of instruments
- urinary catheter for bladder decompression during surgery.
- **Paralumbar fossa** is aseptically prepared (15 cm of the dorsal mid line, flank or stifle fold ventrally, 13^{th} /14^{th} rib cranially, caudal border of tuber coxae caudally).

- 20 ml of 2% Mepivacaine Hcl is injected S/C and I/M at proposed port sites.
- Laparoscopy tower is placed **behind** the horse.

❖ Port sites: -

- **A) Scope port: between 17th & 18th ribs** (5 cm ventral to T. coxae)
- **B) First port:** mid-way between last rib & tuber coxae.
- **C) second port:** 10 cm ventral to first instrumental port.

- Local anesthetic as mepavacaine Hcl 2% (20ml) is administrated to mesovarium & mesosalpinx via **dorsal** instrument port using laparoscopic injection needle.
- Grasping forceps inserted in the **lower** while Ligasure in the **dorsal** instrumental portal.
- mesovarium & mesosalpinx were cauterized in **cranial to caudal direction**.

❖ Ovarian extraction: -

- **A) For Small ovaries (< 10 cm):** dorsal or ventral instrument portal can extend ventrally.
- **B) For Large ovaries (10 – 30 cm):**

  - incision can be extended connecting both instrument portals.

  - using retrieval bags.

  - hand-assisted bagging of the ovaries → Disadvantage: Poor visualization due to loss of pneumoperitoneum.

  - motorized morecellator but it is expensive.

- muscle and skin closure in anatomic fashion.

❖ Post-operative care: -

- Gradual return to normal feeding.
- penicillin 22000 u/Kg I/M and phenyl butazone 2.2 mg/Kg I/V for 3-5 days.
- discharge after 48 hrs. after surgery.
- hand walk for 30 min.
- gradual return to work (one month post-operative).

❖ Complications: -

- bleeding from the body wall due to injury to the cranial branch of **caudal circumflex iliac artery** (Treatment→ ligation).
- uterine horn perforation during dissection.
- bleeding from transected mesovarium.
- tumor metastasis (rare).

- Stallion like behavior disappear within 2 weeks - 6 months post-operative.
- **Removing the enlarged ovary** in standing horse is the **most difficult** part of the surgery.

3- Adhesiolysis

- **Adhesion**: - abnormal fibrous, vascular connections between unusual locations.
- complications of celiotomies includes: adhesions, peritonitis, ileus and it is prevalent in 26 % of horses that had laparotomies.
- **Foals**: have increased susceptibility to adhesions.
- preventive measures include peritoneal lavage, antibiotics, heparin, lubricants administration.
- Diagnosis: via ultrasonography or rectal palpation.
- Breaking down of adhesions occur laparoscopically via dissection, electro surgery, ultrasound, and laser.

❖ Indications: -
- adhesion associated with acute, recurrent abdominal pain, weight loss and colic.
- when open approach is not possible due to anatomical location or inability to put horse under general anesthesia.

❖ Timing for reduction of adhesions: -
- **10 - 21 days after initial surgery** (fibrinous easy to lyse).
- Before: adhesions reform again.
- After: adhesion more fibrous & difficult to break down.

❖ Contraindications: -
- procedure incite de novo adhesion (**0.5% ferric hyalouronate gel**)
- injury to other surrounding tissue may be induced.

❖ Patient positioning: -
- **Both standing & dorsally recumbent positioning** according to:

1- horse behavior
2- surgeon preference
3- ability to withstand general anesthesia
4- anatomical location of adhesions.

- for **dorsal** content, **standing approach** is indicated.
- for **ventral** adhesion, **dorsal recumbency** is indicated.
- **Trendelenburg** for adhesiolysis in **caudal** abdomen.
- **reverse Trendelenburg** for adhesiolysis in **cranial** abdomen.

❖ Instrumentation: -

- 0 or 30-degree scope
- Babcock forceps.
- advanced modalities: e.g. Laser, us, radiofrequency.
- Metzenbaum scissors
- Electro surgery (mono or bipolar)

- NB: - any dissection of mesentery should be done **close to intestinal serosa** to prevent mesenteric rents.
- 300 ml of 0.5% **ferric hyalouronate gel** should be administered after laparoscopic adhesiolysis to prevent reformation & de novo adhesions.

❖ Port Placement: -

- **A) in dorsal recumbency**:
  - The first port: caudal to xiphoid cartilage (lateral to linea alba).
  - The second port: caudal to umbilicus by 1cm (10 cm lateral to linea alba).
  - The third port: contralateral to the second port.
- **B) in standing horse**: traditional approach (in Para lumbar fossa) with one port in last ICS.

❖ Post-operative care: -

- antibiotics (Enrofloxacin, ceftiofur, penicillin)
- NSAIDs (flunixin meglumine)
- prevent ileus & enhance GIT motility

❖ Complications: -

- mesenteric rents.
- De novo adhesions to portal incision

4- Closure of nephrosplenic space
Nephrosplenic space Ablation (NSSA)

- ❖ Indications: -
    - For **treatment of LDDLC** which is more prevalent in **geldings**.
    - Recurrence rates are 20 %.
- ❖ Diagnosis: -
    - Rectal examination.
    - Ultrasonography.
- ❖ Prevention: -
    - Colopexy.
    - Partial colon resection.
    - Closure or obliteration of NSS.
- ❖ Preparation: -
    - withholding the food 24 hrs. pre-operative → to reduce volume of ingesta in large colon.
    - free choice of water
    - tetanus, antibiotics, NSAIDs administration.
    - left paralumbar fossa is aseptically prepared.
    - 20 ml of mepivacaine 2% for portal sites.
    - **Standing position**
- ❖ Port placement (3 ports): -
    - the first: mid-way bet last rib & tuber coxae → scope insertion → CO_2 insufflation.
    - the second: in 17^{th} ICS.
    - the third: 5 cm ventral to the first portal.

- The first portal is replaced by 25 mm cannula trocar assembly to help insertion of 30 mm needle size **1 USP Biosyn**.
- The nephrosplenic space is closed by apposing the **perirenal fascia to dorsomedial splenic capsule in cranial to caudal direction** (Cr →Cd).
- At the end of NSS, modified Roeder knot or surgeon's knot is performed using laparoscopic needle holder.

- ❖ Post-operative care: -
    - systemic antibiotic & anti-inflammatory for 2 days

- control rectal examination after 4 weeks post-operative
- hand walking twice daily after 2 weeks.

❖ Complications: -

• pneumothorax
• Hemorrhage
• Spleen or bowel puncture
•Tearing of suture at fascia or capsule (tissue bite should be large enough in size).

B) Equine Thoracoscopy

❖ Instrumentation: -

• 58 cm long, 10 mm in diameter rigid telescope (30^{o}).
• 11 mm or 15 mm cannula with sharp trocar + stopcock.
• **suction unit** is vital for successful completion of Thoracoscopy.
•other surgical instrument. e.g. Babcock, biopsy forceps, Ligasure.

❖ sedative and analgesia in equine Thoracoscopy: -

- Thoracoscopy is commonly performed in **standing horses** to avoid compaction of general anesthesia and to effective viewing of thoracic anatomy is awake horses
- analgesia is provided by infusing portals with local anesthetic (5ml Carbocaine 2%).
- sedation is attained by IV administration of detomidine or xylazine combined with Butrophanol (0.1 mg / kg).
- **Detomidine is preferred over xylazine** for its: -
  - Long lasting effect
  - profound sedative analgesic effect
- 100 % oxygen administration is an important measure to ensure safe completion of Thoracoscopy.
- oxygen is administered via **nasal insufflation**.
- It is important to evacuate air as much as you can from the thorax upon completion of Thoracoscopy to avoid post-operative pneumothorax.

- broad spectrum antibiotic combination should be given pre-operatively in case of elective lung biopsy and chest trauma in addition to fluxixin meglumine (1.1 mg/kg I.V BID) to decrease pleural inflammation and for systemic analgesia.
- The **13th ICS** is commonly used as the site for endoscopic point placement (Proximal portion of intercostal space just ventral to longissimus dorsi muscle). As more cranial positions (as 8th &9th lCS) will hinder cranial & caudal movement of telescope.

❖ Indications: -

- **A) Thoracoscopic-assisted biopsy**.
- **B) Thoracoscopy in pleuritis and pneumonia.**
- **C)Thoracoscopy in chest trauma.**

❖ **A) Thoracoscopic-assisted biopsy:**

- get samples from multiple tissues during same procedure.
- e.g. lung, mediastinal ln., neoplastic masses as SCC, HSA & lymphoma.
- portals:
  - telescope portal: at 13th ICS.
  - second portal: one or two ICS cranial to scope port & 15 cm ventral to the scope port.
  - Third portal: one or two ICS caudal & ventral to the scope port
- Biopsy could be done with the help of:
  1- 45 mm Endoscopic stapler. (air tight seal is vital)
  2- pre-tied loop ligature
  3- Ligasure.
- N.B: **tension pneumothorax is a life threating complication**.

❖ **B) Thoracoscopy in pleuritis and pneumonia:**

- Performed to: -

  1- Accurate placement of thoracic drains.
  2- necrotic lung & pleural tissue can be debrided & devitalized lung edge can be resected. e.g.: chronic pleuropneumonia.
  3- Thoracic lavage for treatment of acute pleuritis.

❖ **C) Thoracoscopy in chest trauma:**

- Performed to: -

1- removal of retained intrathoracic foreign bodies.
2- assess the extent of lung injury.
3- Thoracic lavage.

- Clinical signs: restlessness, tachycardia, tachypnea, dyspnea, cyanotic mm.
- Cause of this picture is combination of traumatic shock and pneumothorax.
- Tension pneumothorax causes severe cardiopulmonary compromise which leads to cardiopulmonary failure.

❖ **Complications: -**

1- residual post-operative **pneumothorax** is the **most common complication** and diagnosed via post-operative chest radiographs.
2- Intra and post-operative **hemorrhage** associated with inadvertent injury to IC vasculature.
3- **Lung perforation** (commonly in chronic pleuropneumonia due to mature adhesion between lung and pleura).

Introduction to Arthroscopy

❖ **Advantages of arthroscopy: -**

1. Provide more information about intra articular pathology.
2. Magnification, illumination.
3. Clear field of visualization (continuous irrigation)
4. Reduces trauma (compared to arthrotomy).
5. Shorten operative times.
6. Decrease recovery period (dogs discharged in same day).

❖ **Disadvantages of arthroscopy: -**

1. The most difficult of all endoscopies to learn. (Slow long learning curve) which need patience, practice, and persistence to master
2. Narrow and small working space.
3. Anatomic complexity of some joints. (Stifle joint)

❖ **Indications: -**

1- History.
2- Physical examination.

3- Imaging changes.

4- Laboratory changes suggestive for joint disease.

e.g. OCD, MCPD, UAP, DJD, septic arthritis, intra-articular fracture, complete & partial cr.cr. ligament rupture, meniscal injuries could be diagnosed with arthroscopy.

- Septic arthritis management, menisectomy, OCD removal, and debridement of cartilaginous defect are examples for surgical arthroscopic procedures.

❖ **Arthroscopies: -**

- 1.9 - 2.4 - 2.7 - 4 mm arthroscope (30^{o}).
- **2.4 mm is telescope of choice in small animal practice**.

❖ **Telescope sheaths: -**

- have locking mechanism (for water tight seal).

  1.Protect scope from damage, bending stress along scope shaft.

  2. Provide channel for fluid inflow.

❖ **Operative cannulas: -**

- **Advantages:** Facilitate reinsertion of instruments.
- **Disadvantages:**

  1- Limit size of instrument used into joint & size of fragment that can be removed.

  2- Difficult to keep in place.
- Free passage of instrument **<u>without</u>** cannula could be done**:**

  A) Place larger instrument, remove larger pieces of fragments.

  B) Increase difficulty of instrument reinsertion.
- **Sizes:** 2.5 - 3.5 - 4.5 - 5.5 mm.

❖ **Egress cannulas: -**

- Site for fluid outflow from joint.
- Provide distention, removal of debris, maintain clear visual field.
- Sizes: 2.2 - 3.2 - 4.5 mm in diameter (3.2 & 4.5 mm have side stop cocks).

❖ **Operative hand instruments: -**

1- Arthroscopic rongeurs for fragment removal. (Spoon shaped jaws)

2- Grasping forceps. (Alligator shaped)

3- Micro fracture chisels (for osteostixis)

4- Straight & curved curettes (For curetting degenerated tissues).

5- Hook probes (for palpation of articular cartilage).

6- Mosquito hemostats.

7- 20-gauge hypodermic needle (For IA fluid injection).

8- No. 11 scalpel blades.

9- 3 & 12 cm syringes.

10- IV administration set (For joint irrigation).

11- pressure cuffs (to control pressure of fluid).

12- Standard orthopedic surgery set (in case of conversion).

13- Leipzig **stifle distractor**: (used for meniscectomy).

- Provide a room for instrument placement and tissue manipulation.
- Attach to distal Femur and proximal Tibia.
- Increase exposure of menisci.

14- **Power shaver**:

- Remove cartilage, bone, soft tissue.
- Decrease amount of debris left in the joint.
- Blades includes:

    A) Burr: Remove bone & cartilage.

    B) Aggressive curettes: removes soft tissues.

- Speed: 6000 - 15000 RPM.
- A) Reusable Blades: dull too fast, easily broken, too expensive
- B) Disposable blades: autocalvable, used several times, less expensive.
- shaver blades are cannulated to aspirated debris during shaving.
- Hand or foot switch: to change direction of rotation.
- **With <u>small sized joints</u>, <u>foot switch</u> is recommended**.

15- Radiofrequency / electrocautery:

• cut tissue, cauterize bleeding vessels, removal of tissue by vaporization.

e.g. ablation of fat pad, meniscetomy, Cr. Cr. ligament debridement, and ablation of villus synovial proliferation to improve visual field.

❖ **Irrigation fluid management system: -**

- **Types:**

1- Gravity flow.
2- Pressure assisted flow: manual pressure cuffs added to gravity flow system.
3- Mechanical Arthroscopic infusion pump.
   - Excessive fluid pressure lead to rupture of joint capsule.
   - Fluids used includes: Saline, lactated ringer, and ringer solution.
   - Packs: 1, 3, 5 Liter packages.
   - **High flow low pressure system** is effective in maintain clear visual field and decrease the risk of peri-articular fluid accumulation. It is achieved by decreasing outflow resistance.
   - **50 cm H_2O** pressure is recommended for small animal arthroscopy.
   - **Tele pack (**Portable endoscopy unit**)**.

Elbow OCD

- Distal humerus is the common site for OCD particularly **medial ridge** of humeral condyle.
- cartilage different lesions seen include:
  1- free cartilage fragment.
  2- irregular cartilage surface.
  3- coarsely fibrillated cartilage.
  4- fragmented cartilage.
  5- blister like lesion.
  6- double raised cartilage lesion.
- OCD **rarely** seen on lateral ridge of humeral condyle.
- Humeral OCD lesions are seen more frequently with medial coronoid disease(MCPD).

- Arthroscopy for removal and debridement of OCD lesions uses **standard medial telescope approach**.
- Procedure:
  1- removal of free lesion and loose areas of the cartilage.
  2- Avascular bone exposed after cartilage removal is managed by micro fracture chisel or straight curette.
- Hand instrument used for management of OCD as power shaver are too aggressive.
- stem cells injection with joint immobilization.

❖ **Port sites: -** Portal sites on the **medial aspect** of the elbow joint.

- **Ulnar nerve** is palpated on medial aspect of elbow joint just caudal to the scope port.
- First port: distal and caudal to medial epicondyle.
- Second port: over medial coronoid process.
- Third port (egress port): in the olecranon fossa and can be used as an operative portal for UAP Removal.

Stifle Joint Arthroscopy

❖ **Patient positioning: -**

A) for the unilateral stifle arthroscopy: patient is placed either lateral or dorsal recumbency.

B) for the **bilateral** stifle arthroscopy: the patient is placed on the **dorsal recumbency** e.g. bilateral stifle OCD, bilateral CCL rupture.

❖ **Portal sites: -**

- Telescope portal (craniomedial): half way between distal end of the patella & proximal end of tibial crest (Tibial plateau), **medial** to patellar tendon.
- Operative portal (craniolateral): at the same level as the telescope portal just **lateral** to the patellar tendon.
- The egress portal: the **lateral aspect of the supra patellar pouch** is the most practical site for an egress portal in the stifle arthroscopy.
- **No nerves** are at risk with the stifle arthroscopy as all nerves are caudal to the joint.

❖ **Modified outer bridge chondromalacia grading system: -**

- Grade 0: Normal cartilage.
- Grade 1: Blister, swelling, softening.
- Grade 2: Fibrillation, fissure, partial loss of thickness (<50%) or less than 1.5 cm in diameter.
- Grade 3: Fibrillation, fissure, partial loss of thickness (>50%) or more than 1.5 cm in diameter.
- Grade 4: Full thickness loss of the cartilage with exposed bone.
- Grade 5: Full thickness loss of the cartilage with exposed eburnated bone.

❖ **Pathological finding in CCL injuries: -**

1) extensive villus synovial reaction.

- initial finding on entering stifle j. with cruciate ligament pathology.
- It is found throughout the joint.
- e.g.: in supra patellar pouch, medial, lateral joint space, cranial & caudal compartment of the joint.
- its severity is related to **chronicity**. (Not location)
- Shape: very vascular, fronds, and ghost (Avascular).

2) synovial membrane petechiae.

- formation range from petechiae to ecchymotic lesions.

3) vascular pannus (fibrovascular tissue on Avascular area)

- manifestation of synovial proliferation.
- extending over cartilage, menisci (fibro-cartilage), ligaments.
- pannus not formed in articular cartilage surface as animal weight bearing & contact forces destroy blood vessels.
- **potential source of hemarthrosis**.

4) osteophytes.

- formed at the margin of articular surface.
- **suprapatellar pouch** is the **common site** for **stifle osteophytes** → extending proximally to the trochlear groove.

- multiple irregular bony proliferation with the shallow separations giving the shape of (**cobble stone appearance**).

5) chondromalacia (cartilage degenerative lesion).

- include all grades of chondromalacia throughout the joint.

6) meniscal injury.

- include small bucket handle tears, larges bucket handles tears.
- **lateral** meniscus is affected **more frequently** than the medial meniscus (lateral > medial).

- Stifle examination is helpful to assess the extent of CCL injuries, define the meniscal tears & grade chondromalacia.
- It is greatly facilitated by partial fat pad resection & partial synovectomy of villus synovial reaction.
- Minimal ligament injuries can be detected (even in absence of visible ruptured fibers) by presence of **cross striations** in intact ligament indicating that normal tension has been taken off.

❖ **Management of CCL injuries: -**

- Arthroscopic debridement of minor ligament injuries.
- Remnant resection of major partial tears.
- Debriding meniscal injuries.

- Radiofrequency is used to remove the fat pad & villus reaction.
- power shaver is used to remove end of the ligament followed by RF to smooth the remnant of the ligament ends (shaver → RF).
- partial & total menisectomies are performed with power shaver, hand piece instrument →**Duck bill meniscus cutter** → followed by RF to smooth margin.

❖ **Arthroscopic Complications: -**

A) potential complications:

- failure to enter the joint (common with the beginner).

- articular cartilage damage → due to needle placement, operative portal placement, telescope trocar, power instrument, RF leading to linear cut or full - thickness damage.
- soft tissue damage. e.g. **subscapularis tendon** in shoulder arthroscopy and **medial collateral ligament** in elbow arthroscopy.
- bone fragments displacement: e.g. shoulder OCD as bone migrate to inaccessible joint space.
- operative debris → clots.
- **red out** → Cause: intra-articular bleeding and controlled by increasing irrigation (flow or pressure).
- peri-articular fluid accumulation: lead to collapse joint capsule & obscure visualization.
- infection: source from unclean instruments.
- vascular injury: cause: S/C blood vessel damage.
- nerve injury: ulnar nerve in elbow arthroscopy.

B) instrument damage:

- Intra-articular instrument breakage. e.g. burr, No. 11 bard parker scalpel blades (extracted with mosquito hemostat).
- telescope breakage:
  - dirty distal telescope lens.
  - bending pressure: produce **black halo** on one side of image.
  - damage to the distal lens: caused by power shaver.
  - leak at distal lens: fog the image & **pocket of fluid** is visible.

❖ **Arthroscopic contraindications: -**

- patient size: according to instrument availability & your ability. They could scope 7 lbs. dog & stifle of rabbits.
- septic arthritis: not considered as a contraindication.
- anesthetic risk → no specific anesthetic risk or contraindication for arthroscopy.

Joint lavage

- visually directed high pressure performed thoroughly until all areas of the joint cavity are visibly clean.
- Rate: 500 ml/ min.
- move scope during lavage & be aware of all synovial sulci.

❖ **Benefits of joint lavage: -**

- Remove inflammatory mediators.
- mechanical action remove debris, debulk micro-organisms.
- reduce the load of destructive radicals & enzymes.
- raise pH from acidic environment produced by infective process.
- improve action of several antimicrobials (aminoglycosides).

- you can add antimicrobials, antiseptic, Dimethyl sulfoxide (DMSO), and fibrinolytic agents to the lavage fluid.
- Popular combinations include: combination of benzyl penicillin (2.5 million IU) + gentamycin sulfate (250 mg) or Ceftiofur (500 mg) + amikacin sulfate (500 mg).
- Antiseptic → cause synovial irritation (even diluted).
- DMSO → negative effect on cartilage metabolism.

Physics, Facts, Artifacts, and basic interpretation of diagnostic ultrasound

Ultrasound is defined as any sound frequency above the normal hearing range of the human ear i.e. greater than 20.000 hertz, frequencies commonly used in diagnostic ultrasound range from 1 to 10 megahertz (MHz).

Production:

Ultrasound is produced by transducers or probes housing crystals with piezoelectric (pressure-electric) properties. These crystals are deformed by pressure, electricity is produced. Conversely, when an electric current is applied to them, the crystals will deform. This is the process by which ultrasound generated and received by the transducer. Pulsed electrical deformation of the crystals produces sound waves. The transducer acts as both transmitter and receiver, the ultrasound beam of the sound waves is emitted in pulses (1000/s).

Properties of the ultrasound:

Sound is a mechanical wave of compression and rarefaction within a medium. A sound wave can be compared to a longitudinal wave having a wavelength, frequency, and velocity. The frequency is the number of cycles or wavelengths occurring in a given time period (Sec.). Frequently is described in terms of cycles/sec or hertz (Hz). US imaging uses the same pulse-echo principle. Shorts bursts of ultrasound are emitted into the body. These short bursts travel through the body at a constant speed until they meet a reflecting surface. At the reflecting surface, a small portion of the sound beam is reflected back to the transducer and the rest of the sound beam continues through the patient, sending back echoes at all reflecting surfaces. The ultrasound scanner converts this information into dots of light on a screen. The position of the dot on the screen is proportional to the actual distance traveled. Therefore, it could be able to reconstruct an image of the tissues and organs traversed by the sound beam and to measure their relative sizes and their position in relation to the transducer.

Ultrasound Display Mode:

There are **three** main display formats or modes:

1- Amplitude mode (A mode): ultrasonic imaging is one-dimensional display of returning echo amplitude and distance.

2- Brightness mode (B mode): is two-dimensional displays of dots. The transducer is moved across the surface of the body, and cross sectional anatomy is depicted. The brightness of the dots is proportional to the amplitude of returning echoes.

3- Motion mode (Time motion or TM mode): is one-dimensional format displaying dots as B-mode. M-mode is used primarily in echocardiographic studies to measure cardiac wall motion and valve excursions. An actual image of the heart is not produced.

Sound Beam:

Early clinical use of ultrasound showed that focusing of the ultrasound beam was of great importance as the unfocused sound beam diverges rapidly and poor resolution is achieved. The sound beam can be focused by physically bending the crystals (internally focused) or reflected with a mirror (externally focused). Focusing a transducer changes the shape of the sound beam and produces a narrow section of the beam referred to as the focal zone, the midpoint of which is called the focal point. The focal zone of transducer is that part of the sound beam where focusing, and consequently image resolution is optimal. In the near field of the sound beam, or **Fresnel zone**, complex diffraction patterns may occur. Beyond the focal zone, the beam begins to diverge rapidly and resolution diminishes, this is termed **Fraunhofer zone**. The clinical relevance of this is that it is important to place the structure under examination within the focal zone by appropriate selection of the transducer and adaptation of the scanning technique if necessary.

A stand-off may be used to increase the distance between the transducer and the skin surface and thus bring the organ of interest into the focal zone. A stand-off may be composed of any material which is echolucent and does not attenuate the sound beam, e.g. water filled bag or a block of semisolid gel.

Transducer types:

1- Linear array transducer:

These transducers usually have about 400 small crystals arranged in a line, each 5 small crystals forming a major crystal; consequently, each transducer has 80 major crystals. These crystals are operated in turn giving a rectangular field of view. Electronic focusing can be used to improve image resolution. The main advantage of these types of transducers is allowing large field of view, even close to the scanning surface, which facilitates recognition of structures and the anatomical relationship between them. The major disadvantage is that they require a relatively large contact area with the body surface. Some linear array transducers are designed with a convex scanning surface. This gives a mildly diverging field of view, but the advantages and disadvantages of these curved linear array transducers are much the same as the flat design.

2- Sector transducer:

These transducers produce a fan-shaped field of view. A wide-angled fan allows more structures to be seen but gives poorer resolution than a smaller-angled fan.

a- Mechanical sector scanners: Have a small number of crystals which are driven mechanically to sweep out a fan-shaped beam. This is achieved by mounting a small number of crystals on a rotating wheel, or by using a single crystal which oscillates to and fro.

b- Phased array sectors. Use a fixed array of crystals which are electronically triggered to sweep the ultrasound beam through a fan-shaped field. The sector scanners in general have the advantage of being small and easy to use, and they require only a small skin contact area. However, they have a smaller field of view, making it more difficult to identify and relate structures. The near field is particularly restricted. The phased array sector transducers are technically superior to mechanically driven sector transducers. Because the resolution is better, there are no moving parts to wear out, and they do not produce a sense of vibration when applied to the skin. However, they are currently more expensive.

Interaction of the sound beam with tissues

The sound beam is attenuated as it travels through the patient, at a rate of 1 decibel/cm/MHz. The propagation of US in the biological tissues will be under the influence of physical effects. These effects are absorption, scatter, attenuation, refraction and reflection.

Absorption: Portions of the sound beam can be absorbed by the tissues as heat. For practical purposes, if an ultrasound transducers were to be emitted.

Scattering: Occurs when the small irregular surface is insolated. The sound beam will be scattered in all directions in an unpredictable manner. A small portion of the scattered energy makes it back to the transducer. The rest is lost, reducing the energy in a traveling ultrasound wave or ultrasound beam.

Attenuation: The combination of scattering and absorption accounts for most of the energy lost from an ultrasound and absorption accounts for most of the energy lost from an ultrasound wave traveling through tissue. The overall effect is called attenuation, which is expressed as a distance and frequently dependent loss of energy from a traveling ultrasound wave. Attenuation is decibel (dB); the decibel unit is used in ultrasound to express changes in signals strength due to attenuation or amplification.

Reflection: Refers to small portions of the ultrasound bear that strike reflective surfaces and are returned back to the transducer. This is a portion of the sound beam that forms the basis of ultrasound imaging. Acoustic impedance is a function of material density and its propagation velocity. These two properties have an important influence on the design and operation of any sonograph.

$$Z=PC$$

Where Z is acoustic impedance, P is tissue density, and C is the propagation velocity. Each interface with a change in acoustic impedance reflects a portion of the incident energy, and these reflections combined to form the final image on the display screen. The strength of reflection is directly proportional to the difference in acoustic impedance across the interface. The greater the difference is the greater the reflected energy. In general, the brightest echo

signals on a display will come from specular reflections, and the softer echo signals will come from scattering. The best images of structures and boundaries usually come from specular reflections. This requires that the ultrasound beam be perpendicular to the reflecting surface.

Table 1: Velocity, Reflection and Transmission of the sound waves in body tissues.

Substance	Velocity (m/s)	Reflection (%)	Transmission (%)
Air	330	99.88	0.12
Water	1480-1500	0.00	100.00
Bone	2700-4100	46.00	54.00
Fat	1470-1480	0.12	99.88
Muscle	1545-1630	0.48	99.52
Brain	1520-1530	0.11	99.89
Liver	1550-1570	0.30	99.70

Resolution

Resolution is the ability to detect small differences in tissue density. The resolution of an ultrasound image is dependent upon the wavelength. Therefore, increasing the frequency would decrease the wavelength and increase the resolution. High-frequency transducers were used to image superficial structures and take advantages of high resolution. There are two types of resolution involved in ultrasound imaging. Axial resolution refers to the ability to distinguish between two objects placed close together along the path of the sound pulse beam and this function of ultrasonic pulse length. The smaller the axial resolution, the better is the image. In other word, a system having an axial resolution of 2 mm is better than a system having axial resolution of 4 mm, Lateral resolution; this refers to the ability to distinguish between two echo forming surfaces lying side by side in relationship to the sound beam. Lateral resolution is best in the focal zone where the beam is narrowest. Lateral resolution is determined by the beam's diameter. Most modern transducers employ some degree of focusing to ensure good lateral resolution.

Time-Gain Compensation

Sound beam is diminished in intensity by approximately 1 decibel/cm/MHz. This means equal acoustic interfaces located at different distances from the scan head will return unequal echoes. This will pose a problem if there were no means to compensate for it. TGC control, which is on all sonograph, allows the operator to selectively increase echoes returning from distant regions of the patient. If the Time-Gain is too high, a densely echoic zone will appear near the skin surface and deeper echoes will be within an acceptable intensity range. If the TGC is too low, acceptable intensity echoes will appear near the transducer, but there will be no deep echoes. The Time-Gain compensation must be adjusted while performing scan to prove an even image.

Image Recording

All modern ultrasound equipment allows the display image to be frozen. It is of great importance that there is the facility to record this frozen images, as this allows subsequent examination and discussion of the image and enables accurate comparisons to be made on follow up examinations. It also allows a library of the ultrasonographic appearance of normal and diseased organs to be compiled.

There are a number of options available for the recording the frozen image:

1- Polaroid camera:

This is a simple and cheap system. The major disadvantage is that the Polaroid images are of poor quality.

2- Video printers:

These images have fairly recently become available. They produce rapid reproductions of the frozen image on paper at very little cost. The prints are of excellent quality, although they unfortunately have the tendency to turn yellow-brown with time.

3- Multiformat camera:

These cameras may be automatic or manual, but both types are expensive to purchase. Images are produced on X-ray film, which is processed routinely to produce a permanent image of excellent quality. The multiformat

camera is certainly the method of echoic for recording the frozen image, but the initial cost may sometimes place it out of reach.

Ultrasound Image Artifacts

An artifact on B-mode, gray scale ultrasound image has been defined as any dot appearing in the ultrasound image that does not correspond to a real echo in the patient. A good understanding of the physical principles of ultrasound waves, equipment and their interaction of the part being examined is essential in distinguishing between reality and artifacts. On the other hand, the presence of artifacts can sometimes even be helped and give additional information.

1- Noises (Rauschen): This artifact appears as multiple small bright dots all over the image and this is due to moving electrons on the monitor. This artifact is caused by increase in the TGC. To avoid such artifact, the time gain compensation should be reduced.

2- Reverberation: Reverberation artifacts are the most frequent and troublesome artifacts produced on ultrasound images. Reverberation artifacts are produced by a sound pulse bouncing back and forth between two interfaces. They may be produced by sound waves reflecting between the transducer and tissue interfaces of internally between two reflecting interfaces.

A- With transducer-interface reverberation only the initial echoes are real; other reverberation echoes that appear deeper in the tissue will be multiples of the original transducer-interface echo and succeeding reverberation echoes will be smaller because of attenuation. Transducer-interface reverberations are more likely to occur from highly reflective interfaces i.e. gas and bone.

B- Internal structure-structure reverberations occur when the sound pulse bounces back and forth between two tissue interfaces.

a- Comet-tail or Ring-down: It occurs when the sound hits a metallic structure, such as lead shot or caused by a highly reflective interface, most commonly the air-fluid interface between bowel wall and bowel gas. In this situation, the sound bounces back and forth numerous times within the structure, each time sending some of the sound back to the transducer. This, therefore,

appears on the screen as numerous tiny parallel echoes deep to the structure. It can sometimes resemble a vertical line but this is only because the echoes are so closely spaced.

b- Mirror image: Whereas reverberations and ring downs are reflections that occur back and forth within the direction of the original sound beam, a mirror image artifact is one in which the sound beam is deflected away from the transducer. It is also known as a multipath reflection. The reflected sound may hit a strong interface, be bounced back to the "mirror" and then back to the transducer.

3- Shadows: Shadows in ultrasound may be due to reflection, absorption or refraction

A- Reflective: Reflective or absorptive shadows are entirely analogues to the shadow cast by a tree in the sun. All of the light is reflected and/or absorbed by the tree trunk so that there is relative shadow on the far side with ultrasound, all of the sound beam must be blocked by a reflecting gallstone or calcification to produce a shadow. There should be an echo from the near side of the structure as well. It is possible to produce an echo without a shadow if the structure impinges on part of the sound beam without being large enough to block it completely. It is therefore, possible to have gallstones without shadowing or small clumps of calcification that do not produce shadow.

B- Refractive (Lateral shadowing); another kind of shadowing occurs at the edge of structures when the sound beam passes through an oblique interface. When the sound passes through a curved or oblique interface, some of the sound beam can be refracted away from the central line. This can result in a defocusing of the sound beam deep to the oblique interface. Therefore, the echoes returning from the real interfaces deep to the edge of such a structure are significantly less intense, hence, a shadow e.g. edge of the foetal skull, cysts, and bladder.

4- Distant enhancement: Enhancement is the opposite of shadowing. As the sound beam passes through a relatively anechoic medium, the returning echoes are more intense and less attenuation takes place than in the surrounding echogenic areas. When the sound beam strikes the wall of this cystic structure, the echoes appear to be brighter than the surrounding

structure. This is confirmation of the presence of an anechoic structure such as the urinary bladder or a cyst.

5- Beam thickness: This artifact may appear as low level echoes in the dependent portion of a fluid collection. This can mimic debris or pus while the fluid is actually clear. When the sound beam is directed obliquely to meet an organ of high difference echogenic pattern e.g. urinary bladder which appeared on the monitor as very thin. This is due to not all the crystals are fired in the same time i.e. producing narrow beam. The wall of the urinary bladder appeared not sharply defined and pseudo-sedimentation or artificial sedimentation. To overcome such artifact, the angle of the transducer should be redirected or the patient rolled into the side

Basic Interpretation Principles

1- When viewing gray-scale ultrasound scans the scanning surface or near field should be uppermost. Longitudinal, sagittal or para-sagittal scans should be oriented with cranial aspect of the animal to the viewer's left and caudal aspect of the viewer right.

2- Bone and gas have highly reflective interfaces and effective gray scale ultrasound imaging can't be performed through either gas or bone. Fat is more echoic than water dense tissues and can be identified when surrounded by water dense structures.

3- Parenchymal organs have characteristic echo patterns based on varying cellularity and stromal connective tissue results in increased echoes. Parenchymal organs of least densely echoic to most densely echoic are: kidney, liver, spleen and prostate.

4- Diffuse echoic pattern of an organ may be reduced by infiltrative processes such as edema or increased by fibrous tissue; fatty infiltration or diffuse neoplastic cellular infiltration such as changes in organ echogenicity may also be the result of technical machine settings.

Internal echo patterns are anechoic, hypoechoic, echoic and complex. The echo pattern of any lesion is relative to the echogenicity of the adjacent tissue.

5- Anechoic lesions are usually fluid filled. The fluid of this pattern is usually non viscous. Hypoechoic patterns may be seen with abscess or other cystic

structures containing viscous fluid, haematoma or neoplasm e.g. lymphosarcoma. Echoic and complex patterns are usually associated with neoplastic lesions; however, haematomas and granulomas in some cases may be echoic. Complex lesions are a combination of echoic and hyperechoic areas. Complex lesions may result from necrotic or fluid filled cystic areas.

A number of terms may be used to describe the image:

*** Hyperechoic, echogenic:** A bright echo, appearing white on conventional scans this represent highly-reflective interfaces e.g. bone, gas, and connective tissue.

*** Intermediate echoes:** gray echoes, this represents parenchymal organs.

*** Hypoechoic, echopoor:** Sparse echoes, appearing dark gray on conventional scans, this represent lymph node, abscess, and hematoma.

*** Anechoic, Echolucent, sonolucent:** absence of echoes, appearing black on conventional scans, this represents complete transmission of sound e.g. fluid.

Table 2: Comparative advantages and disadvantages of radiography and sonography.

	Radiography	**Ultrasonography**
1	Summation image	Image in sections
2	Limited time consumption	More time consumption
3	Limited processing	Long time processing
4	Good judgment of bone & gas	No judgment of bone & gas
5	Radiation hazards	No Radiation hazards (repeated)
6	No judgment of internal structures	Good judgment of internal structures
7	Organ boundaries not always clear	Organ boundaries always clear
8	Poor details when fluids are present	Good details when fluids are present
9	Expensive establishment	Less expensive establishment