

# **HD-S Device Surgical Manual**



## **Acknowledgments**

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HD-S Device Surgical Manual  
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# Introduction

The HD-S devices are surgically implanted in laboratory animals to acquire research data as part of the PhysioTel HD telemetry system. They can detect internal animal characteristics (e.g. blood pressure, ventricular pressure, pulmonary artery pressure, ECG, and heart rate), process the information into data, and transmit the data from within the animals via radio-frequency signals. In addition to transmission of physiological data, the HD-S devices also provide digital data that contain the implant's serial number, factory calibrations, device ON time and battery voltage. This manual contains detailed procedures for implantation of the HD-S telemetry devices to acquire a variety of pressure signal combinations and ECG. The techniques described are designed for rats but may be applicable to other, similarly sized animals.

The HD-S devices are available in three configurations: the HD-S10, equipped with one pressure catheter, the HD-S11, equipped with one pressure catheter and one set of biopotential leads, and the HD-S21, equipped with two pressure catheters and one set of biopotential leads.

More information about operating the HD-S system may be found in the DSI Implantable Telemetry System Manual (007678-003).

The HD-S Device Surgical Manual is intended for use by lab personnel who will perform, or assist in, the surgical procedures to implant devices into animals for use with PhysioTel HD Telemetry Systems. HD-S users must ensure they have the appropriate software to accommodate their implants; contact your sales representative if your version of software does not contain the option for your implant model.

The surgical procedures written in this manual are at a level of detail appropriate for persons who have previous experience with animal surgical procedures in similarly sized species. These devices should only be implanted by a person who has previous experience with animal surgical procedures.

**WARNING: The HD-S implantable devices are not intended for use in humans. It is a misuse of these devices, and a possible violation of law, to use these devices in humans.**

# Required Supplies for the HD-S Surgery

Some equipment needs may vary depending on the type of surgical procedure chosen to perform. Please refer to the Small Animal Surgical Supplies technical note at [www.datasci.com](http://www.datasci.com) for a complete listing of required lab supplies.

## Rodent Anesthesia Guidelines

Surgical anesthesia in rodents is often challenging. Individual anesthetic protocols should be tested for each animal strain and variation before attempting survival surgery. Typically, the surgical procedure will require 90-120 minutes of surgical anesthesia. Please consult your staff veterinarian for proper anesthetic protocols and training. The surgical procedures described in this manual were developed using inhalation anesthesia consisting of Isoflurane and Oxygen.

The following anesthetic regimen should only be used as a guide and should be modified to the individual animal and institution's protocol.

### Inhalation using Isoflurane and Oxygen:

#### Rats

1. Induction: 3% Isoflurane and 1 liter per minute of Oxygen
2. Maintenance: 2% Isoflurane and ½ liter per minute of Oxygen

Anesthetized rodents are predisposed to hypothermia and hyperthermia because of their small size. The use of supplemental heat sources such as warm water bottles, heating pads, or thermal lamps are important to maintain baseline body temperature. Both hypothermia and hyperthermia will prolong the recovery period and may result in death of the animal.

Proper anesthesia and aseptic technique are important for proper wound recovery and humane treatment of laboratory animals. For additional help in determining which anesthetic protocol is suitable for you, contact your staff veterinarian or refer to the Anesthesia Reference Manual (391-0055-001) prepared by DSI as a guide to assist you in choosing an appropriate anesthetic agent for a wide variety of common laboratory species.

# Peri-operative Antibiotics and Analgesics

The use of peri-operative antibiotics may be applied at the discretion of the investigator. The combination of sterile implant packaging and proper aseptic technique are typically the only requirements necessary for successful surgical outcomes. Investigators should follow the guidelines of their own institution. Questions regarding the use of antibiotics should be directed to your staff veterinarian.

The use of pre- and post-surgical analgesics is strongly encouraged for all surgical manipulations performed on laboratory animals. “An integral component of veterinary medical care is prevention or alleviation of pain associated with procedural and surgical protocols. . . The selection of appropriate analgesics and anesthetics should reflect professional veterinary judgment as to which best meets clinical and humane requirements as well as the needs of the research protocol.”<sup>1</sup> Questions regarding the use of analgesics should be directed to your staff veterinarian.

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<sup>1</sup> Guide for the Care and Use of Laboratory Animals, Eighth Edition, NRC, *National Academy Press*, 2011

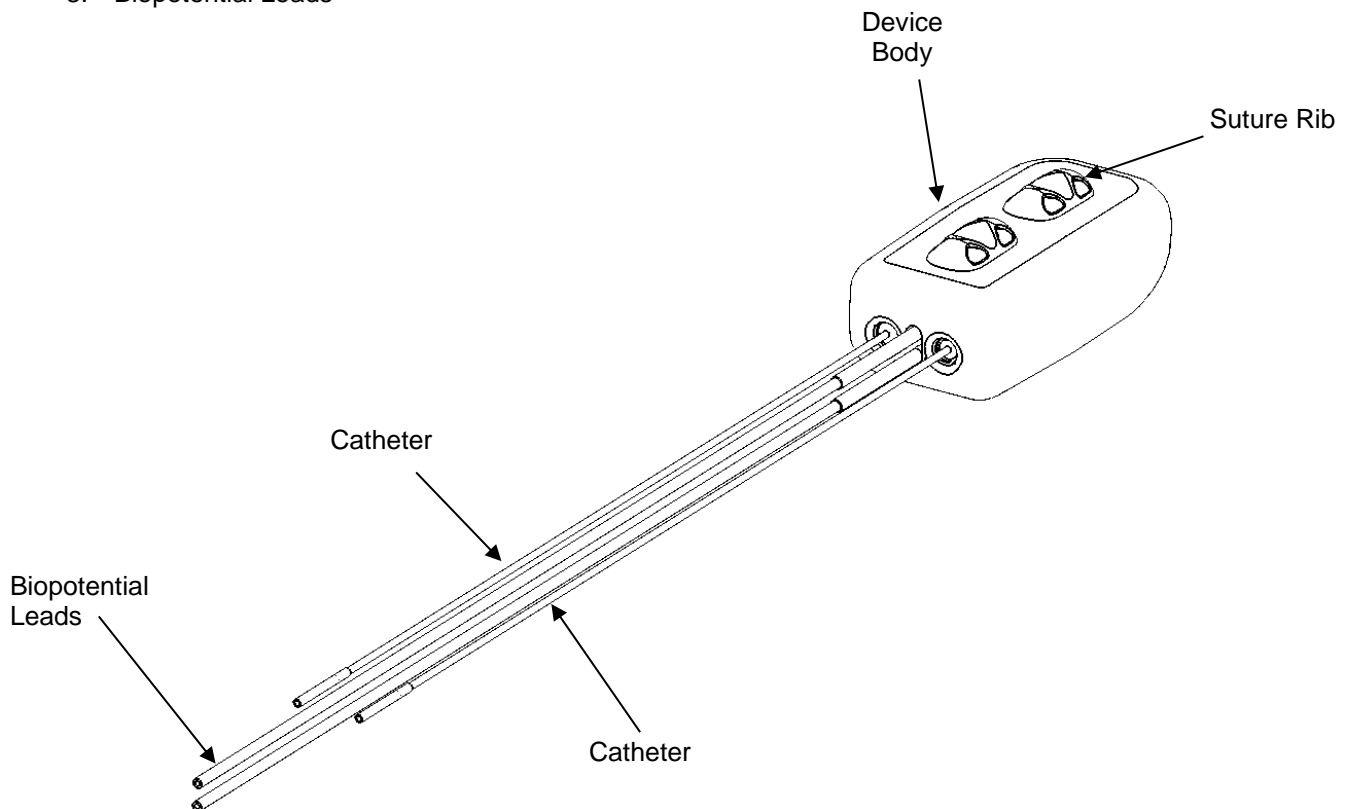
# HD-S21 Device Description

The HD-S21 measures two pressures, a biopotential signal, temperature, and physical activity in rats and other similarly sized animals. It is a flat device with rounded edges, two catheters and a pair of biopotential leads. Suture ribs are an optional feature and are made of a soft, flexible material. For suture rib handling recommendations and best practices, please refer to the Proper Techniques for Maximizing the Use of the Suture Rib technical note at [www.datasci.com](http://www.datasci.com).

It is important that you are familiar with the HD-S21 device and its function before you attempt implantation. Please refer to the DSI Implantable Telemetry System Manual (007678-003) for complete details.

The devices consist of the following major components:

1. Device Body
  - Suture rib (optional, showing)
2. Pressure Catheter
3. Biopotential Leads



**Figure 1: HD-S21 implant**  
(With suture rib side showing)

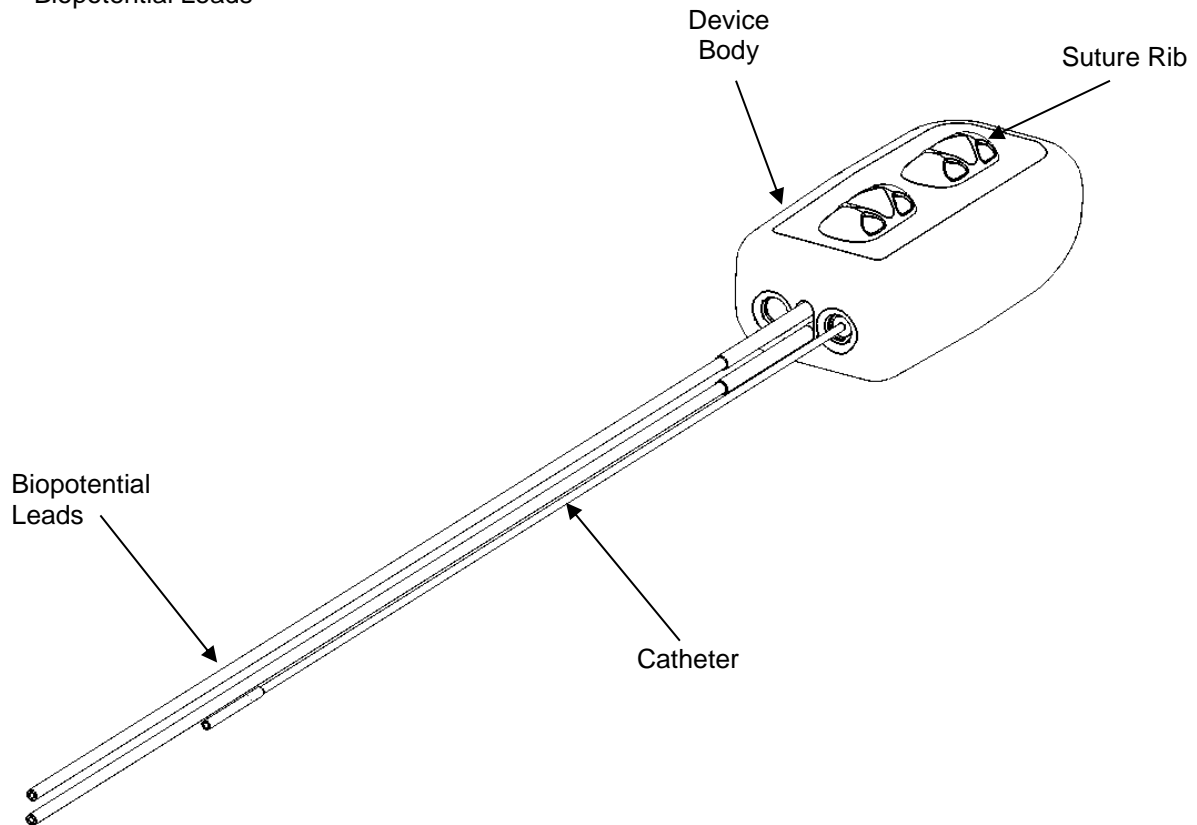
# HD-S11 Device Description

The HD-S11 measures one pressure, a biopotential signal, temperature, and physical activity in rats and other similarly sized animals. It is a flat device with rounded edges, one catheter and a pair of biopotential leads. Suture ribs are an optional feature and are made of a soft, flexible material. For suture rib handling recommendations and best practices, please refer to Proper Techniques for Maximizing the Use of the Suture Rib technical note at [www.datasci.com](http://www.datasci.com). The HD-S11 is available in two different radio frequencies (F0 and F2) to allow for pair housing or dual implantation with another device, i.e. HD-XG (See Appendix C for more information).

It is important that you are familiar with the HD-S11 device and its function before you attempt implantation. Please refer to the DSI Implantable Telemetry System Manual (007678-003) for complete details.

The devices consist of the following major components:

1. Device Body
  - Suture rib (optional, showing)
2. Pressure Catheter
3. Biopotential Leads



**Figure 2: HD-S11 implant**  
(With suture rib side showing)



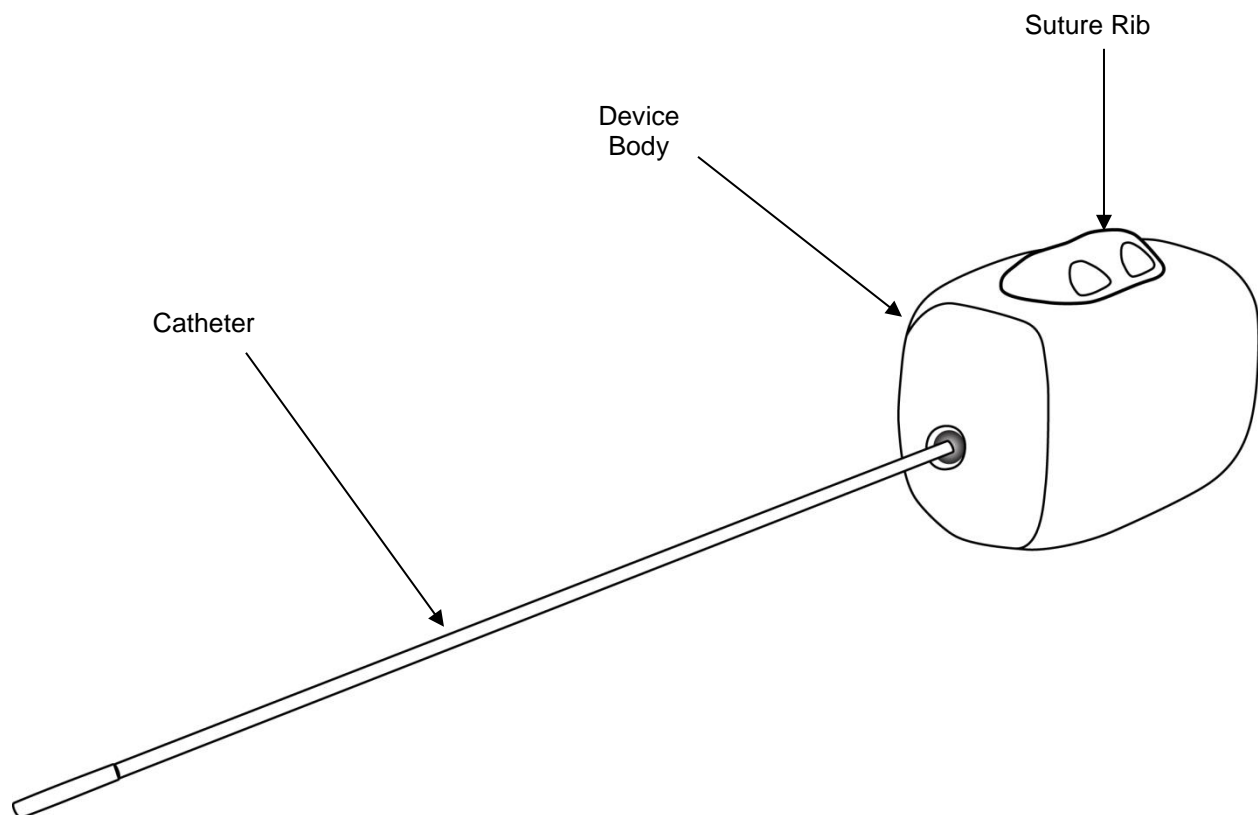
# HD-S10 Device Description

The HD-S10 measures one pressure, temperature, and physical activity in rats and other similarly sized animals. It is a teardrop-shaped device with rounded edges and one catheter. Suture ribs are an optional feature and are made of a soft, flexible material. For suture rib handling recommendations and best practices, please refer to Proper Techniques for Maximizing the Use of the Suture Rib technical note at [www.datasci.com](http://www.datasci.com). The HD-S10 has optimized the ASIC configuration for various performance parameters including battery life, range, and sample rate. One side effect of this optimized configuration is that that you will no longer be able to use the a.m. radio to detect changes in pressure, which means it does not produce an audible pulsatile tone and tone should not be used to confirm or deny proper catheter placement in the vessel.

It is important that you are familiar with the HD-S10 device and its function before you attempt implantation. Please refer to the DSI Implantable Telemetry System Manual (007678-003) for complete details.

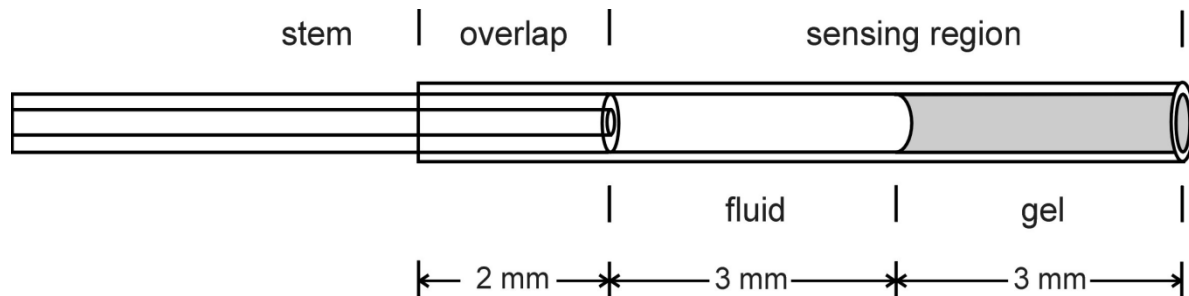
The devices consist of the following major components:

1. Device Body
  - Suture rib (optional, showing)
2. Pressure Catheter



**Figure 3: HD-S10 implant**  
(With suture rib side showing)

It is also important to be familiar with the catheter and its features. The catheter is filled with a non-compressible fill fluid and a gel plug at the tip and thus must be handled with great care. **Mishandling the catheter will result in damage to the pressure sensor.** Please refer to the Preventing Damaged Sensors in Blood Pressure Implants technical note at [www.datasci.com](http://www.datasci.com) for further information. See Figure 4 for a detailed diagram of the catheter.



**Figure 4: Blood Pressure Catheter**  
(Optional ligation aid available for HD-S21 and HD-S11 not shown)

## Device Implantation Site Selection

HD-S implants can be placed either subcutaneously or in the abdominal cavity in animals that are at least 175 grams in weight. However, in most applications, intraperitoneal placement will be most appropriate. If the abdominal aorta is to be cannulated, it is imperative that the diameter of the aorta is at least twice as large as the diameter of the catheter to allow for sufficient blood flow to the hind limbs. Vessel diameter may vary among different strains and the minimum weight may need to be adjusted to ensure the aorta is large enough to accommodate the catheter.

If the collection of core body temperature is required, the implant must be placed in the abdominal cavity. If the device is placed subcutaneously, ensure that it lies flat under the skin and that the subcutaneous pocket is large enough to accommodate the implant comfortably.

# Surgical Implantation of the HD-S Device

This section of the manual describes surgical procedures to obtain pressure measurements from multiple locations and ECG. The manual is designed to pick a primary catheter location and, if applicable, then advance to the aortic blood pressure catheter and ECG lead placement. However, other pressure combinations may be desirable. Please refer to Appendix D for catheter configuration options.

Before starting surgery, record the pressure offset from each pressure channel of the implant and hydrate the catheter(s) by following the proceeding directions.



**Before removing the implant from its sterile package:**

1. Turn the implant to the ON mode with a magnet and audibly verify proper implant operation with a radio tuned to the low end of the AM band. DSI recommends turning the implant on 1-4 hours before implantation to allow the electronic components to stabilize.
2. Record the serial number of the implant and ensure that the device has been identified with the animal in which it will be implanted.
3. Measure and record the pressure offset from each pressure channel. For help with this process, refer to the DSI Implantable Telemetry System Manual (007678-003).
4. If implanting for the first time, verify that the Battery ON TIME for the implant reads "0 days" in the software. Sampling must be started to obtain this information, which will be derived from saving the data trace.



**To hydrate the catheters:**

1. Open the sterile package by peeling back the white package cover from the clear plastic tray. Do not discard the white package cover as it contains important device calibration information. Also do not discard the sterile package as it can be used for eventual return of the implant to DSI.
2. Lift the clear tray cover and flood the channels where the catheter(s) lay with sterile saline. At this time, do not touch the implant or sterile inner tray. This may compromise sterility.

3. Replace the clear tray cover and set the package aside until you are ready to transfer the device to your sterile surgical field. The catheter(s) should be hydrated for approximately 15-30 minutes before implantation.

***Note: The catheters are very hydrophilic and, if not hydrated, will absorb water from the blood. This can cause the gel to recede due to catheter expansion and leave a void at the tip of the catheter, which could increase the risk of blood clot formation.***



### ***Surgical Preparation***

1. Administer the appropriate surgical anesthesia.
2. Apply Artificial Tears eye ointment to each eye.
3. Remove the body hair liberally from all intended incision sites.
4. Surgically scrub the incision sites with Chlorhexidine scrub and sterile saline. A series of three scrubs with both the disinfectant soap and sterile saline is recommended.
5. Once the animal is prepared for surgery and a sterile field has been established, the surgery is ready to begin.

**If an intra-thoracic procedure is to be performed, the animal must be placed on a ventilator to maintain respiration. The animal should be placed on the ventilator prior to establishing a sterile field. For more information regarding the use of a ventilator, please see Appendix B.**



### ***Left Ventricle Cannulation via the Diaphragm***



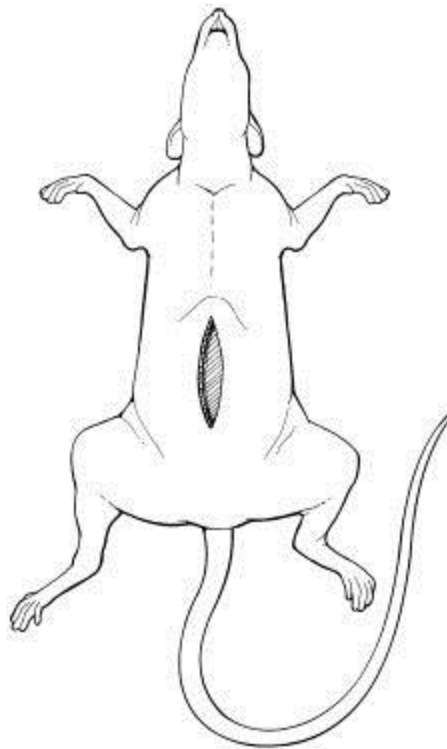
**IMPORTANT: The HD-S10 device is NOT acceptable to use for left ventricle cannulation due to limitations of the device frequency response. Please ensure ONLY the HD-S21 or HD-S11 devices are used for this procedure.**

A thoracotomy approach is a suitable and the most reliable method to obtain left ventricular (LV) pressure. Only the trans-diaphragm approach will be discussed in this manual. Use the shortest possible catheter length for this application; in most species, an 8 cm long catheter is recommended for use.

When two pressure channels are present (HD-S21), the Channel 1 catheter will first be placed in the left ventricle of the heart. The Channel 2 catheter will then be placed for systemic blood pressure followed by the biopotential leads, which will be routed subcutaneously to collect an ECG signal. The implant will be placed in the abdominal cavity. Please refer to Appendix D for catheter configuration options.

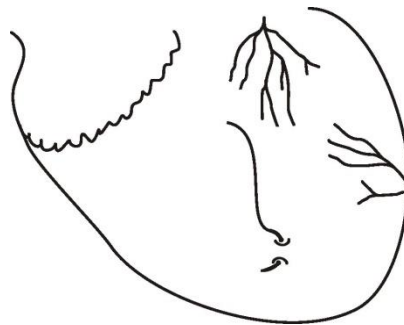
**Tissue hydration should be maintained throughout the procedure.**

1. Position the animal in dorsal recumbency on the surgery table with the feet closest to the surgeon. Provide supplemental warmth during surgery.
2. Loosely tape the animal's limbs to the table.
3. Establish a sterile field and apply sterile draping material.
4. Using a scalpel blade, make a 4-5 cm midline incision through the skin on the abdomen. The incision should extend cranially to the xyphoid process.
5. Use blunt dissection to gently separate the skin from the abdominal wall around the incision.
6. Using small surgical scissors make a 4-5 cm midline incision through the abdominal wall. The incision should extend cranially to the xyphoid process. Take care not to damage internal organs. (See Figure 5)



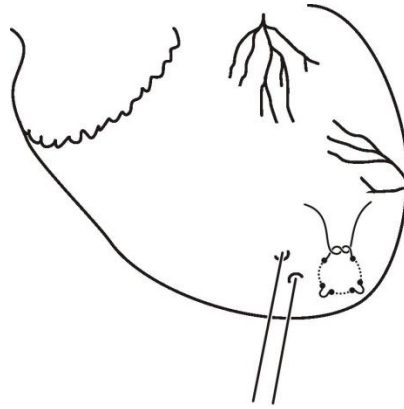
**Figure 5: Ventral abdominal incision**

7. Depress the liver and surrounding intestines with saline moistened 2 x 2 cm gauze. The liver should stay depressed until the diaphragm is fully closed again. (A sterile tongue depressor or something similar in size and shape may aid in keeping the liver depressed during the surgery.)
8. At this point, the abdominal wall can be retracted using a magnetic arch assembly and small animal retraction system if desired. See Appendix D for more information.
9. Incise the diaphragm from the ventral aspect dorsally approximately 5 mm to the right of the midline.
10. Keep the diaphragm open by placing a separate 6-0 non-absorbable suture (silk) with a taper point needle through the diaphragm on each side of the incision and tying it to the abdominal wall. **Using anything other than a taper point needle will damage the tissue.**
11. Remove the pericardium from around the heart. **Take care not to grasp the heart.**
12. Locate the apex of the heart. This is where the catheter will be inserted.
13. Place an anchor suture superficially through the myocardium just to the left of the apex. (See Figure 6) This should be done using size 6-0 non-absorbable suture (silk) with a taper point needle. **Using anything other than a taper point needle will damage the tissue. Take care not to grasp the heart. Do not retract the heart at this time.**



**Figure 6: Placement of the anchor suture**

14. Identify the target area at the apex of the heart and install a loose purse-string suture through the myocardium. (See Figure 7) This should be done using 6-0 non-absorbable suture (silk) with a taper point needle. **Using anything other than a taper point needle will damage the tissue.** The purse-string suture should be anchored in the myocardium 3 times. **Take care not to grasp the heart. Do not retract the heart at this time.**



**Figure 7: Placement of the purse-string suture**

15. Remove the implant from the sterile package and transfer it to the sterile field. **Do not handle the implant by grasping the catheter. This may cause damage to the catheter or the pressure sensor. See the Preventing Damaged Sensors in Blood Pressure Implants technical note on [www.datasci.com](http://www.datasci.com).**
16. Turn the AM radio on and carefully remove the tip cover from the LV catheter (Channel 1). Removal of the tip cover should be done by alternating gentle traction and release. **Take care to prevent gel loss due to compression of the catheter or sudden release of the tip cover. Always examine the catheter under high magnification prior to implantation for gel loss or bubbles. If there is gel loss or bubbles, the catheter will need to be re-gelled. For help with this process, refer to the Guidelines for the Re-gel of Small Animal Catheters on our website: [www.datasci.com](http://www.datasci.com) A video clip of this procedure is also available on our website.**
17. Tie a piece of non-absorbable suture around the suture aid on the catheter. (See Figure 8) The specific size of the suture is not critical but a color that is different from the purse-string suture may be helpful.



**Figure 8: Suture around the suture aid**

***The process of inserting the catheter into the left ventricle is an intricate maneuver and needs to be performed quickly and efficiently in order to prevent damage to the heart.***

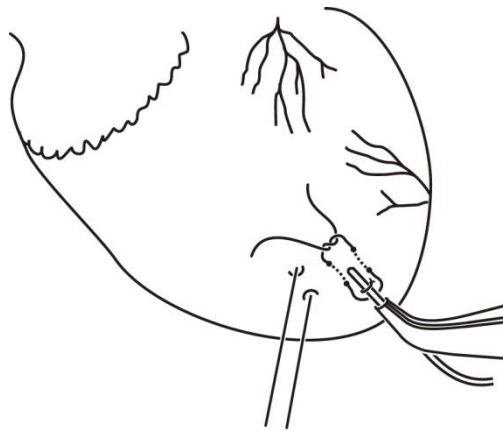
18. Gently apply tension to the anchor suture using a hemostat. This will stop the heart from beating normally.
19. Place a cotton tip applicator in the hand that will not be used for cannulation.

20. Using the vessel cannulation forceps in the other hand, grasp the hub of a 20-gauge needle.
21. Puncture the heart in the center of the purse-string suture and verify perforation into the left ventricle by the presence of blood in the needle. (See Figure 9)



**Figure 9: Puncture the heart wall**

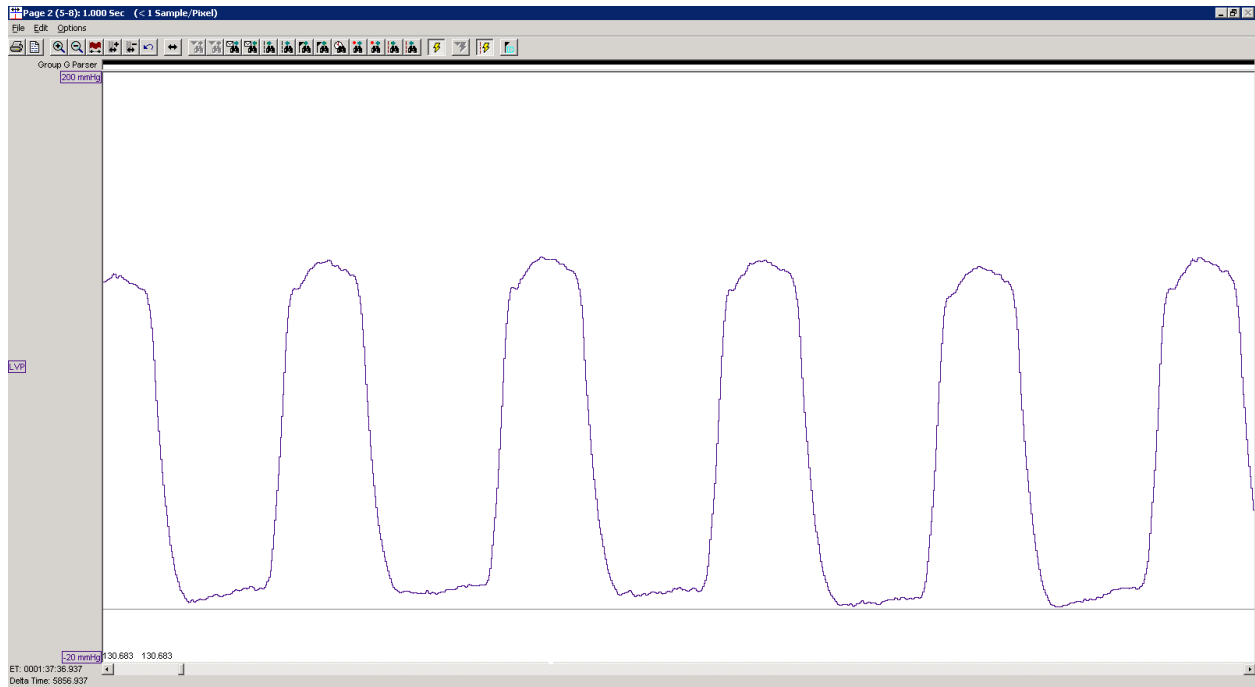
22. Withdraw the needle and apply the cotton tip applicator to the perforation.
23. Drop the needle and using the vessel cannulation forceps, grasp the overlap section of the catheter.
24. Insert the tip of the catheter into the perforation in the heart wall. Advance the catheter until the suture aid suture on the catheter is in direct contact with the heart wall. (See Figure 10)  
**Releasing the grasp on the catheter at this point may cause the catheter to withdraw from the heart. Keep grasping the catheter until the purse-string suture is tightened.**





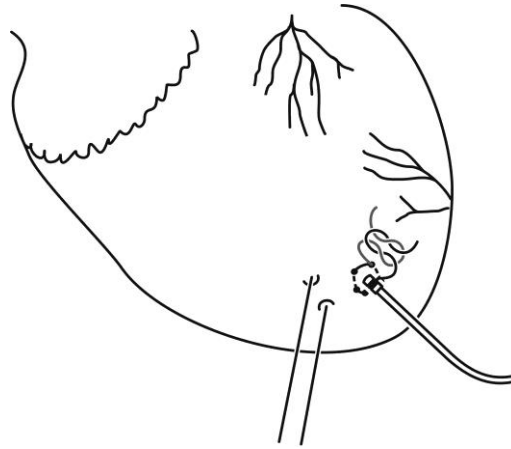
**Figure 10: Insertion of the catheter**

25. Gently draw the purse-string suture closed around the catheter. **Ensure this suture is tight so the catheter will not withdraw from the heart.**
26. Release the tension on the anchor suture. This will allow the heart to return to its normal position.
27. Monitor the left ventricular pressure signal with the software system to verify proper placement. (See Figure 11)



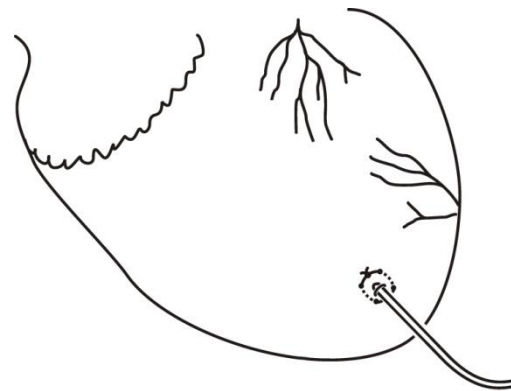
**Figure 11: Left ventricular pressure signal**

28. Continue securing the purse-string suture with at least two more knots.
29. Tie one tail of the suture aid suture together with one tail of the purse-string suture and secure. (See Figure 12)



**Figure 12: Secure the suture tails**

30. Repeat the above step for the other two suture tails.
31. Completely remove the anchor suture from the heart wall and cut the other sutures as short as possible. A small drop of Vetbond may be applied to the catheter insertion site to aid in securing the catheter in place. (See Figure 13)



**Figure 13: Catheter tied in place**

32. Optimize the orientation of the catheter so there is minimal stress on the catheter.
33. Remove all blood or fluid from the thoracic cavity.
34. Remove the retraction sutures from the diaphragm to allow for closure.
35. Position the catheter through the ventral aspect of the diaphragm incision.

36. Starting at the dorsal aspect of the diaphragm incision, suture the diaphragm closed using 6-0 non-absorbable suture (silk) with a taper point needle. **Using anything other than a taper point needle will damage the tissue.** The diaphragm should be sutured in a simple continuous pattern.
37. Insert a 25-gauge IV catheter through an intercostal space prior to completely closing the diaphragm.
38. Attach a 3-way stopcock and 10 ml syringe to the IV catheter to allow for easy withdrawal of air.
39. Evacuate the thoracic cavity to restore negative pressure. Close the stopcock to the IV catheter.
40. Complete the closing of the diaphragm incision and check for air leaks.
41. Re-open the stopcock to allow air withdrawal and evacuate the thoracic cavity again to restore negative pressure. **Negative pressure is restored when resistance is felt while trying to withdraw the air from the chest cavity. Insure that the IV catheter is not against a portion of the lungs as this can also cause resistance.**  
  
***It is critical to restore negative pressure within the chest cavity as soon as possible after the closure of the diaphragm. The animal may have difficulty breathing and could die if negative pressure is not achieved.***
42. Completely withdraw the IV catheter from the thoracic cavity and remove the gauze and any other retraction devices that may have been used from the abdominal cavity. **Additional air evacuation of the thoracic cavity may be needed after the retraction devices are removed.**
43. Irrigate the abdominal cavity with sterile saline.
44. Proceed to the section titled **Abdominal Aorta Cannulation with Intraperitoneal Cavity Device Placement.**



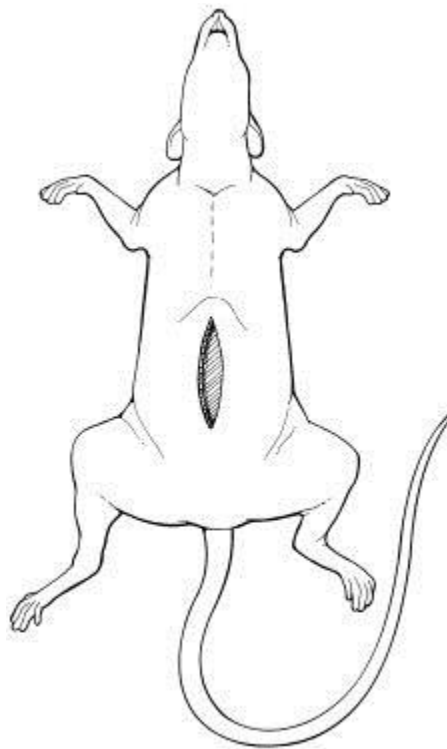
### ***Right Ventricle Cannulation via the Diaphragm***

Both a trans-diaphragm and a thoracotomy approach are suitable methods to obtain right ventricular (RV) pressure. Only the trans-diaphragm approach will be discussed in this manual. In most species, an 8 cm long catheter is recommended for use.

When two pressure channels are present (HD-S21), the Channel 1 catheter will first be placed in the right ventricle of the heart. The Channel 2 catheter will then be placed for systemic blood pressure followed by the biopotential leads, which will be routed subcutaneously to collect an ECG signal. The implant will be placed in the abdominal cavity. Please refer to Appendix D for catheter configuration options.

**Tissue hydration should be maintained throughout the procedure.**

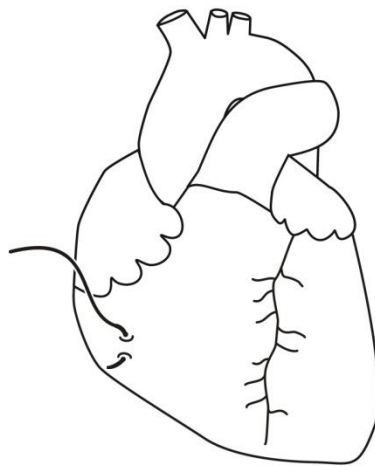
1. Position the animal in dorsal recumbency on the surgery table with the feet closest to the surgeon. Provide supplemental warmth during surgery
2. Loosely tape the animal's limbs to the table.
3. Establish a sterile field and apply sterile draping material.
4. Using a scalpel blade, make a 4-5 cm midline incision through the skin on the abdomen. The incision should extend cranially to the xyphoid process.
5. Use blunt dissection to gently separate the skin from the abdominal wall around the incision.
6. Using small surgical scissors make a 4-5 cm midline incision through the abdominal wall. The incision should extend cranially to the xyphoid process. Take care not to damage internal organs. (See Figure 14)



**Figure 14: Ventral abdominal incision**

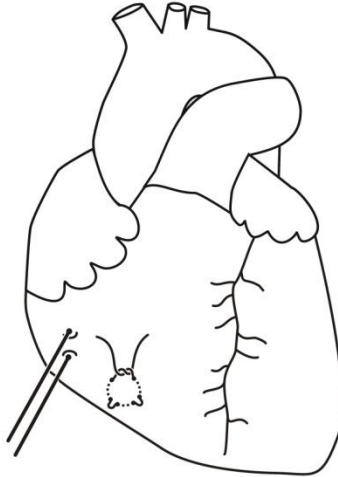
7. Depress the liver and surrounding intestines with saline moistened 2 x 2 cm gauze. The liver should stay depressed until the diaphragm is fully closed again. (A sterile tongue depressor or something similar in size and shape may aid in keeping the liver depressed during the surgery.)
8. At this point, the abdominal wall can be retracted using a magnetic arch assembly and small animal retraction system if desired. See Appendix C for more information.
9. Incise the diaphragm from the ventral aspect dorsally approximately 5 mm to the left of the midline.

10. Keep the diaphragm open by placing a separate 6-0 non-absorbable suture (silk) with a taper point needle through the diaphragm on each side of the incision and tying it to the abdominal wall. **Using anything other than a taper point needle will damage the tissue.**
11. Remove the pericardium from around the heart. **Take care not to grasp the heart.**
12. Locate the apex of the heart. The catheter will be inserted approximately 2-3 mm to the left of the apex.
13. Place an anchor suture superficially through the myocardium below the atria and cardiac veins. (See Figure 15) This should be done using size 6-0 non-absorbable suture (silk) with a taper point needle. **Using anything other than a taper point needle will damage the tissue. Take care not to grasp the heart. Do not retract the heart at this time.**



**Figure 15: Placement of the anchor suture**

14. Identify the target area of the heart halfway between the atria and apex and install a loose purse-string suture through the myocardium. (See Figure 16) This should be done using 6-0 non-absorbable suture (silk) with a taper point needle. **Using anything other than a taper point needle will damage the tissue.** The purse-string suture should be anchored in the myocardium 3 times. **Take care not to grasp the heart. Do not retract the heart at this time.**



**Figure 16: Placement of the purse-string suture**

15. Remove the implant from the sterile package and transfer it to the sterile field. **Do not handle the implant by grasping the catheter. This may cause damage to the catheter or the pressure sensor. See the Preventing Damaged Sensors in Blood Pressure Implants technical note on [www.datasci.com](http://www.datasci.com).**
16. Turn the AM radio on and carefully remove the tip cover from the RV catheter (Channel 1). Removal of the tip cover should be done by alternating gentle traction and release. **Take care to prevent gel loss due to compression of the catheter or sudden release of the tip cover. Always examine the catheter under high magnification prior to implantation for gel loss or bubbles. If there is gel loss or bubbles, the catheter will need to be re-gelled. For help with this process, refer to the Guidelines for the Re-gel of Small Animal Catheters on our website: [www.datasci.com](http://www.datasci.com)** A video clip of this procedure is also available on our website.
17. Tie a piece of non-absorbable suture around the suture aid on the catheter. (See Figure 17) The specific size of the suture is not critical but a color that is different from the purse-string suture may be helpful.

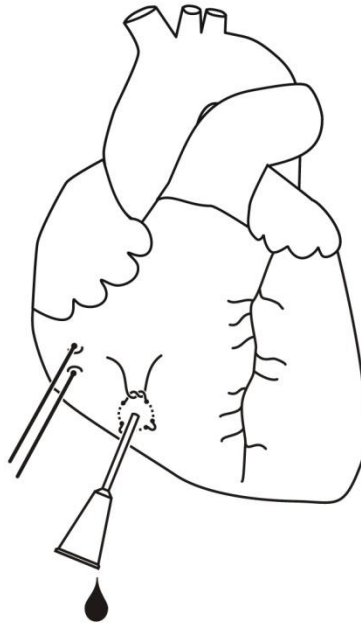


**Figure 17: Suture around the suture aid**

***The process of inserting the catheter into the right ventricle is an intricate maneuver and needs to be performed quickly and efficiently in order to prevent damage to the heart.***

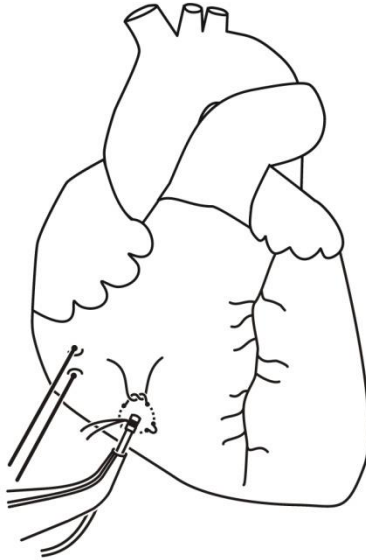
18. Gently apply tension to the anchor suture using a hemostat. This will stop the heart from beating normally.

19. Place a cotton tip applicator in the hand that will not be used for cannulation.
20. Using the vessel cannulation forceps in the other hand, grasp the hub of a 20-gauge needle.
21. Puncture the heart in the center of the purse-string suture and verify perforation into the right ventricle by the presence of blood in the needle. (See Figure 18)



**Figure 18: Puncture the heart wall**

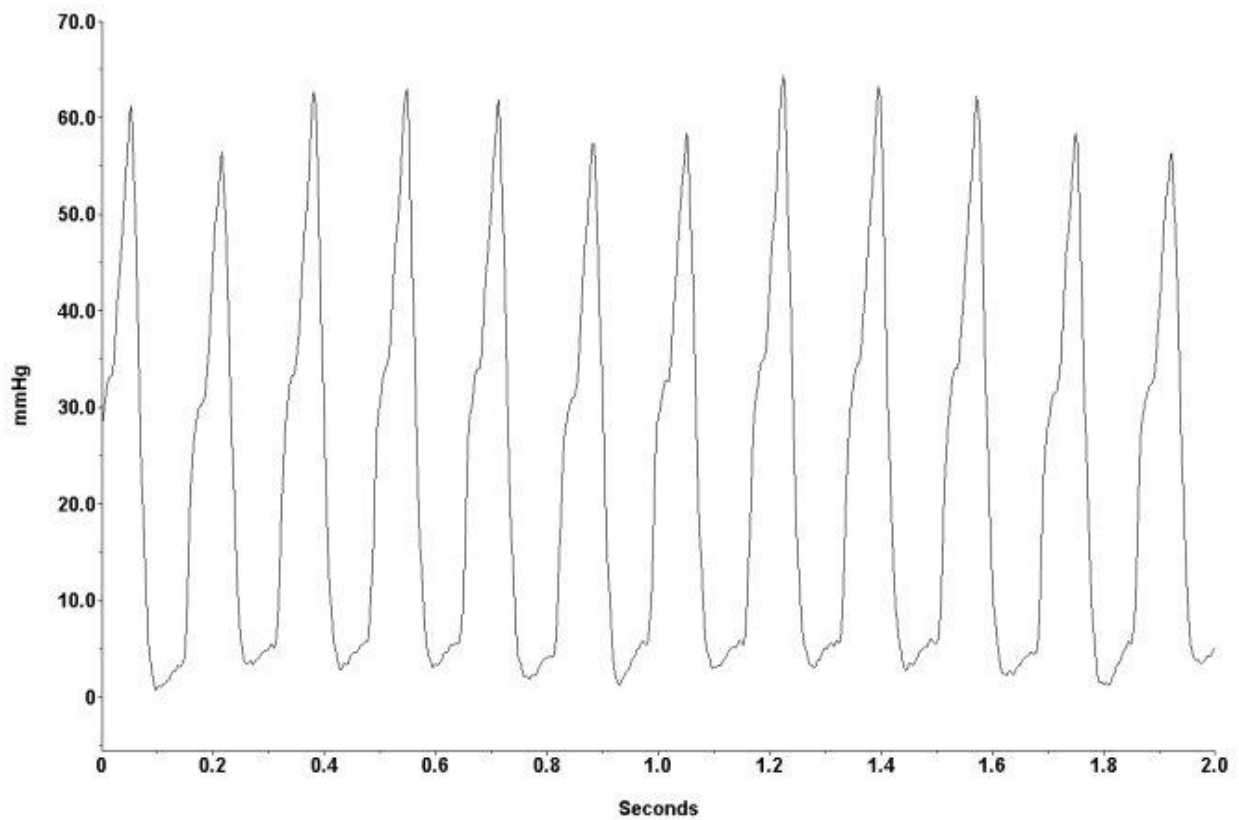
22. Withdraw the needle and apply the cotton tip applicator to the perforation.
23. Drop the needle and using the vessel cannulation forceps, grasp the overlap section of the catheter.
24. Insert the tip of the catheter into the perforation in the heart wall. Advance the catheter until the suture aid suture on the catheter is in direct contact with the heart wall. (See Figure 19)  
**Releasing the grasp on the catheter at this point may cause the catheter to withdraw from the heart. Keep grasping the catheter until the purse-string suture is tightened.**



**Figure 19: Insertion of the catheter**

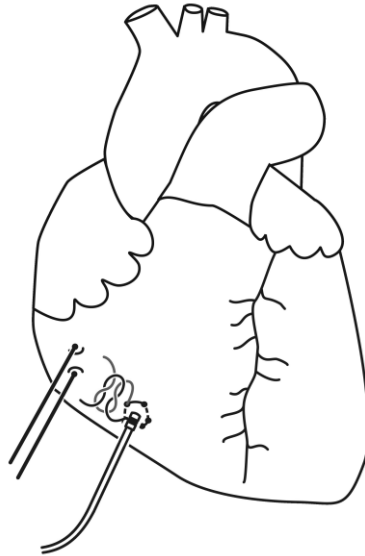
25. Gently draw the purse-string suture closed around the catheter. **Ensure this suture is tight so the catheter will not withdraw from the heart.**
26. Release the tension on the anchor suture. This will allow the heart to return to its normal position.
27. Monitor the right ventricular pressure signal with the software system to verify proper placement. (See Figure 20)





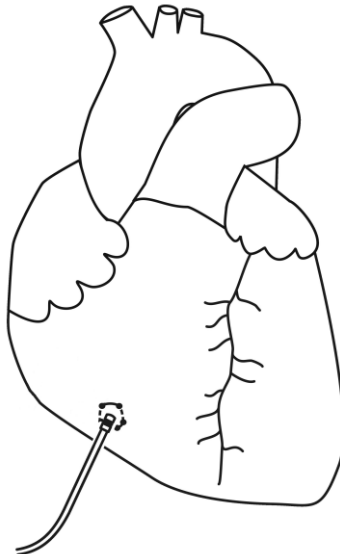
**Figure 20: Right ventricular pressure signal**

28. Continue securing the purse-string suture with at least two more knots.
29. Tie one tail of the suture aid suture together with one tail of the purse-string suture and secure.  
(See Figure 21)



**Figure 21: Secure the suture tails**

30. Repeat the above step for the other two suture tails.
31. Completely remove the anchor suture from the heart wall and cut the other sutures as short as possible. A small drop of Vetbond may be applied to the catheter insertion site to aid in securing the catheter in place. (See Figure 22)



**Figure 22: Catheter tied in place**

32. Optimize the orientation of the catheter so there is minimal stress on the catheter.

33. Remove all blood or fluid from the thoracic cavity.
34. Remove the retraction sutures from the diaphragm to allow for closure.
35. Position the catheter through the ventral aspect of the diaphragm incision.
36. Starting at the dorsal aspect of the diaphragm incision, suture the diaphragm closed using 6-0 non-absorbable suture (silk) with a taper point needle. **Using anything other than a taper point needle will damage the tissue.** The diaphragm should be sutured in a simple continuous pattern.
37. Insert a 25-gauge IV catheter through an intercostal space prior to completely closing the diaphragm.
38. Attach a 3-way stopcock and 10 ml syringe to the IV catheter to allow for easy withdrawal of air.
39. Evacuate the thoracic cavity to restore negative pressure. Close the stopcock to the IV catheter.
40. Complete the closing of the diaphragm incision and check for air leaks.
41. Re-open the stopcock to allow air withdrawal and evacuate the thoracic cavity again to restore negative pressure. **Negative pressure is restored when resistance is felt while trying to withdraw the air from the chest cavity. Insure that the IV catheter is not against a portion of the lungs as this can also cause resistance.**  
  
***It is critical to restore negative pressure within the chest cavity as soon as possible after the closure of the diaphragm. The animal may have difficulty breathing and could die if negative pressure is not achieved.***
42. Completely withdraw the IV catheter from the thoracic cavity and remove the gauze and any other retraction devices that may have been used from the abdominal cavity. **Additional air evacuation of the thoracic cavity may be needed after the retraction devices are removed.**
43. Irrigate the abdominal cavity with sterile saline.
44. Proceed to the section titled **Abdominal Aorta Cannulation with Intraperitoneal Cavity Device Placement.**



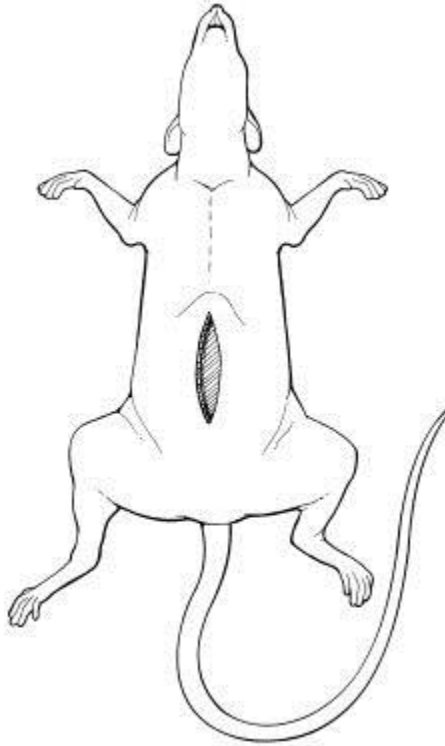
## ***Pulmonary Artery Cannulation via a Thoracotomy***

A right thoracotomy approach is a suitable and the most reliable method to obtain pulmonary artery (PA) pressure. Only the thoracotomy approach will be discussed in this manual. In most species, a 10 cm long catheter is recommended for use.

When two pressure channels are present (HD-S21), the Channel 2 catheter will first be placed for systemic blood pressure followed by the biopotential leads, which will be routed subcutaneously to collect an ECG signal. The implant will be placed in the abdominal cavity and the abdominal cavity will be sutured closed. The Channel 1 catheter will then be placed in the pulmonary artery of the heart. Please refer to Appendix D for catheter configuration options.

**Tissue hydration should be maintained throughout the procedure.**

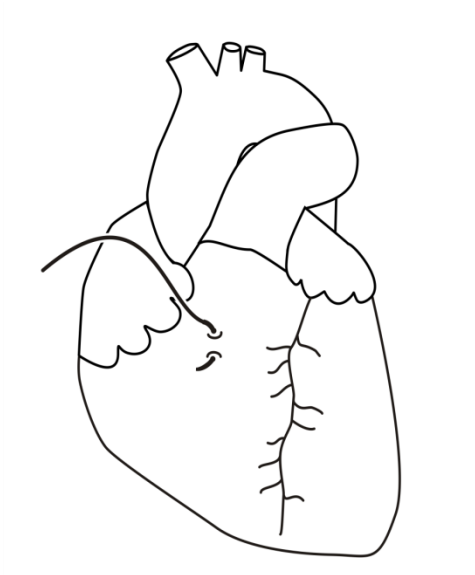
1. Position the animal in dorsal recumbency on the surgery table with the feet closest to the surgeon. Provide supplemental warmth during surgery.
2. Loosely tape the animal's limbs to the table.
3. Establish a sterile field and apply sterile draping material.
4. Using a scalpel blade, make a 4-5 cm midline incision through the skin on the abdomen. The incision should extend cranially to the xyphoid process.
5. Use blunt dissection to gently separate the skin from the abdominal wall around the incision.
6. Using small surgical scissors make a 4-5 cm midline incision through the abdominal wall. Take care not to damage internal organs. (See Figure 23)



**Figure 23: Ventral abdominal incision**

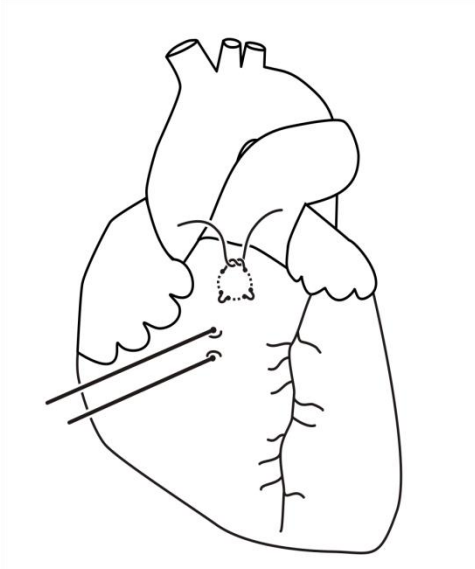
7. Remove the implant from the sterile package and transfer it to the sterile field. **Do not handle the implant by grasping the catheter. This may cause damage to the catheter or the pressure sensor.**
8. Place the systemic blood pressure catheter by proceeding to the section titled **Abdominal Aorta Cannulation with Intraperitoneal Cavity Device Placement** and then follow the section titled **Placement of the ECG Leads**. Place the implant on top of the intestines, parallel to the long axis of the body with the catheter oriented **cranially**. Do not close the abdominal cavity yet. Once those two procedures have been performed, return here to continue on with the rest of the procedure.
9. Pass a 20-gauge needle through the abdominal wall near the right lateral cranial aspect of the incision. Pass the needle from the outside of the incision into the abdominal cavity taking care not to damage any internal organs.
10. Insert the catheter through the lumen of the needle and out of the abdomen.
11. Withdraw the needle leaving the catheter positioned through the abdominal wall.
12. Close the abdominal wall using 4-0 or 5-0 non-absorbable suture with a simple interrupted pattern. Incorporate the suture rib on the implant into the closure.
13. Place sterile, saline-moistened gauze over the abdominal wall and ensure that the abdominal wall and catheter are protected so they do not become contaminated.

14. Un-tape the animal and position the animal on its left lateral side (right side should be up facing you).
15. Establish a sterile field and apply sterile draping material. A change of gloves may be needed at this time.
16. Make a horizontal skin incision over the sixth to seventh intercostal space.
17. Using a metal trocar, tunnel subcutaneously from the abdominal incision to the right intercostal incision.
18. Place the plastic sleeve over the metal trocar and remove the trocar leaving the sleeve in place.
19. Carefully place the catheter in the plastic sleeve and advance it at least 3 cm.
20. Withdraw the plastic sleeve leaving the lead in place. The end of the lead should now be exiting the chest incision.
21. Ensure the sterile, saline-moistened gauze over the abdominal wall is still intact.
22. During exhalation, make a small incision through the intercostal muscle. Extend the incision toward the sternum and the spine as necessary. **Avoid damaging the lungs and internal thoracic vessels.**
23. Tunnel the catheter through the intercostal space and into the thoracic cavity below the incision. This is best achieved by using an 18-gauge needle. By routing the catheter through one intercostal space lower, a better closure will be achieved.
24. Insert an alm retractor to help open the thoracic cavity. **Care should be taken to not over retract as this can cause damage to the ribs.**
25. Remove the pericardium from around the heart. **Take care not to grasp the heart.**
26. Locate the pulmonary artery. The catheter will be inserted just below the artery.
27. Place an anchor suture superficially through the myocardium below the atria and cardiac veins. (See Figure 24) This should be done using size 6-0 non-absorbable suture (silk) with a taper point needle. **Using anything other than a taper point needle will damage the tissue. Take care not to grasp the heart. Do not retract the heart at this time.**



**Figure 24: Placement of the anchor suture**

28. Identify the target area of the heart below the pulmonary artery and install a loose purse-string suture through the myocardium. (See Figure 25) This should be done using 6-0 non-absorbable suture (silk) with a taper point needle. **Using anything other than a taper point needle will damage the tissue.** The purse-string suture should be anchored in the myocardium 3 times. **Take care not to grasp the heart. Do not retract the heart at this time.**



**Figure 25: Placement of the purse-string suture**

29. Turn the AM radio on and carefully remove the tip cover from the PA catheter (Channel 1 if using HD-S21). Removal of the tip cover should be done by alternating gentle traction and release. **Take care to prevent gel loss due to compression of the catheter or sudden release of the tip cover. Always examine the catheter under high magnification prior to implantation for gel loss or bubbles. If there is gel loss or bubbles, the catheter will need to be re-gelled. For help with this process, refer to the Guidelines for the Re-gel of Small Animal Catheters on our website: [www.datasci.com](http://www.datasci.com)** A video clip of this procedure is also available on our website.
30. Tie a piece of non-absorbable suture around the catheter. (See Figure 26) The suture should be secure around the catheter but still moveable. The specific size of the suture is not critical but a color that is different from the purse-string suture may be helpful.

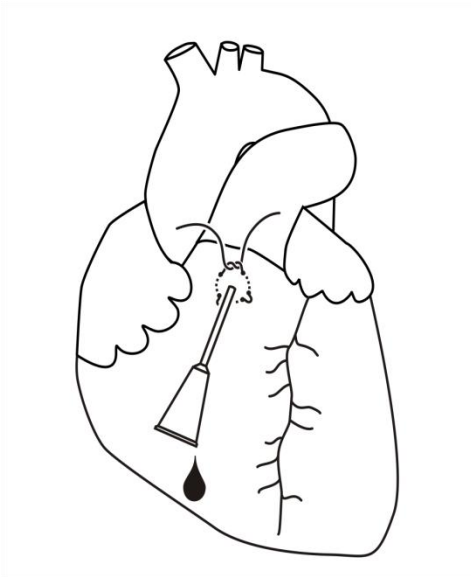


**Figure 26: Suture around the catheter**

***The process of inserting the catheter into the pulmonary artery is an intricate maneuver and needs to be performed quickly and efficiently in order to prevent damage to the heart.***

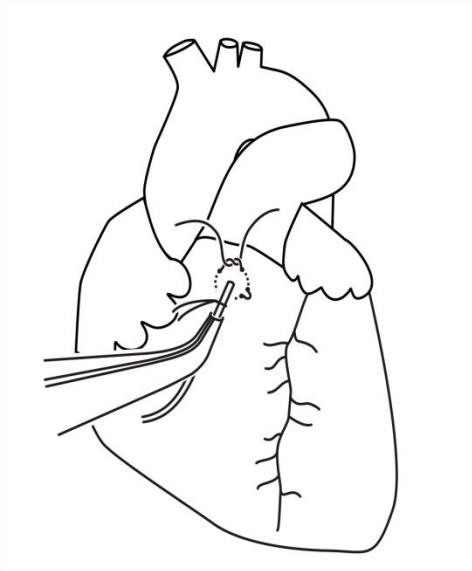
31. Gently apply tension to the anchor suture using a hemostat. This will stop the heart from beating normally.
32. Place a cotton tip applicator in the hand that will not be used for cannulation.
33. Using the vessel cannulation forceps in the other hand, grasp the hub of a 23-gauge needle.
34. Puncture the heart in the center of the purse-string suture and verify perforation into the right ventricle by the presence of blood in the needle. (See Figure 27)





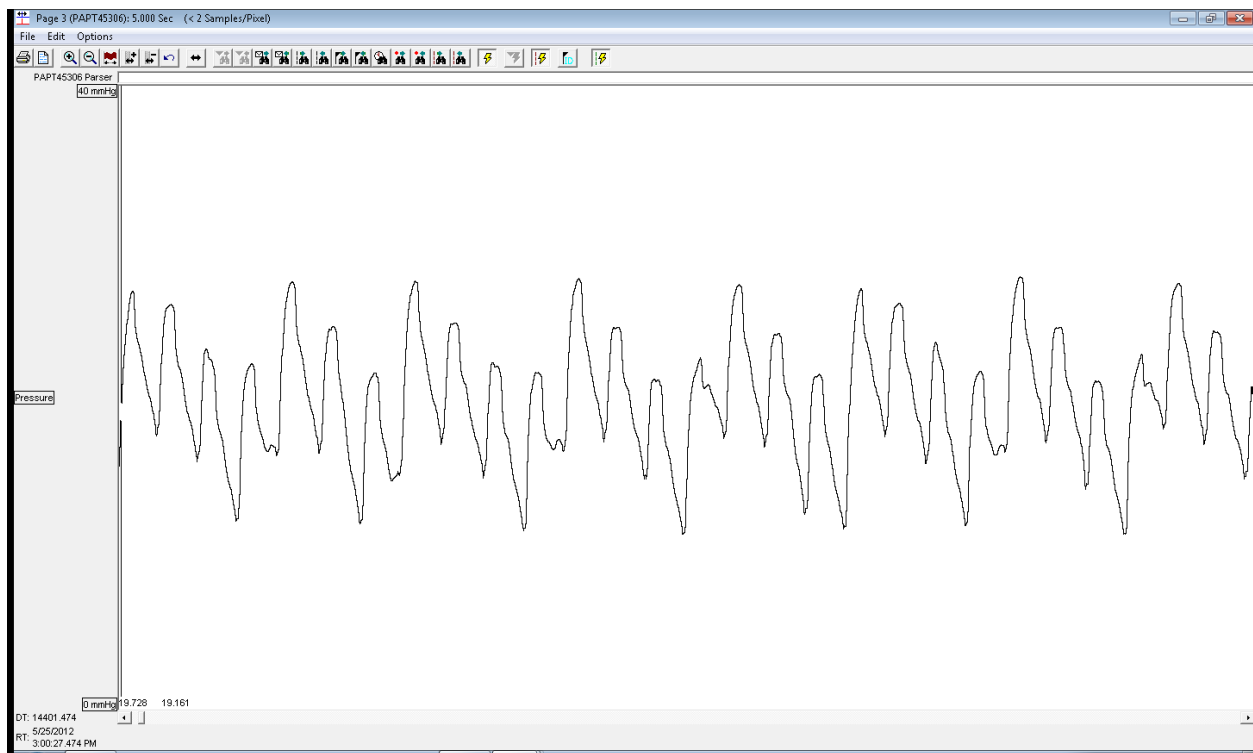
**Figure 27: Puncture the heart wall**

35. Withdraw the needle and apply the cotton tip applicator to the perforation.
36. Drop the needle and using the vessel cannulation forceps, grasp the overlap section of the catheter.
37. Insert the tip of the catheter into the perforation in the heart wall. Advance the catheter into the pulmonary artery. (See Figure 28) **Releasing the grasp on the catheter at this point may cause the catheter to withdraw from the heart. Keep grasping the catheter until the purse-string suture is tightened.**



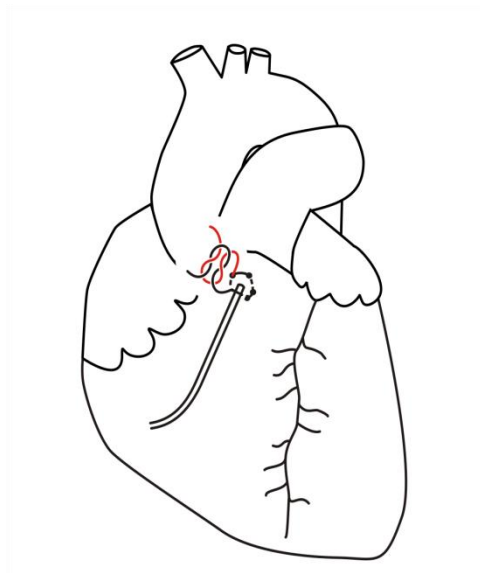
**Figure 28: Insertion of the catheter**

38. Gently draw the purse-string suture closed around the catheter. **Ensure this suture is tight so the catheter will not withdraw from the heart.**
39. Release the tension on the anchor suture. This will allow the heart to return to its normal position.
40. Monitor the pulmonary artery pressure signal with the software system to verify proper placement. (See Figure 29)



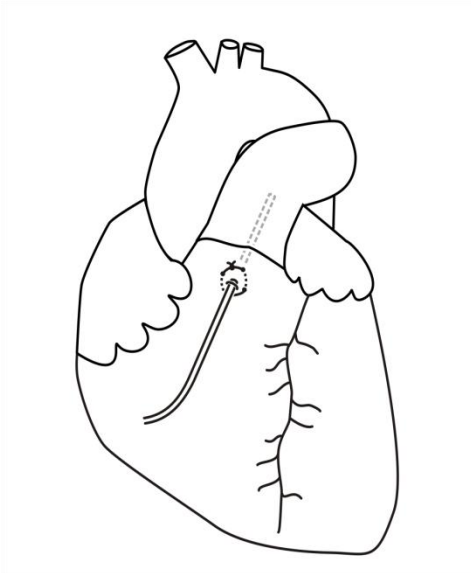
**Figure 29: Pulmonary artery pressure signal**

41. Continue securing the purse-string suture with at least two more knots.
42. Advance the suture around the catheter until it meets the heart wall.
43. Tie one tail of the catheter suture together with one tail of the purse-string suture and secure.  
(See Figure 30)



**Figure 30: Secure the suture tails**

44. Repeat the above step for the other two suture tails.
45. Completely remove the anchor suture from the heart wall and cut the other sutures as short as possible. A small drop of Vetbond may be applied to the catheter insertion site to aid in securing the catheter in place. (See Figure 31)



**Figure 31: Catheter tied in place**

46. Optimize the orientation of the catheter so there is minimal stress on the catheter.
47. Remove all blood or fluid from the thoracic cavity.
48. Place multiple pieces of 4-0 absorbable suture around the ribs. Tension may be placed on the sutures to approximate the ribs while other sutures are being tied.
49. Ensure the ribs have been approximated appropriately and the thoracotomy incision is closed.
50. Insert a 25-gauge IV catheter through an intercostal space prior to completely closing the thoracic cavity.
51. Attach a 3-way stopcock and 10 ml syringe to the IV catheter to allow for easy withdrawal of air.
52. Evacuate the thoracic cavity to restore negative pressure. Close the stopcock to the IV catheter.
53. Re-open the stopcock to allow air withdrawal and evacuate the thoracic cavity again to restore negative pressure. **Negative pressure is restored when resistance is felt while trying to**

withdraw the air from the chest cavity. Insure that the IV catheter is not against a portion of the lungs as this can also cause resistance.

***It is critical to restore negative pressure within the chest cavity as soon as possible after the closure of the diaphragm. The animal may have difficulty breathing and could die if negative pressure is not achieved.***

54. Close the muscle layers of the incision in two layers using 4-0 or 5-0 absorbable suture. A simple continuous pattern should be used. Ensure the needle of the suture does not pierce the catheter.
55. The subcutaneous tissue layer may also be closed using this technique.
56. Re-evacuate the thoracic cavity and monitor for any re-filling of air.
57. Close the skin incision using wound clips or 4-0 or 5-0 absorbable or non-absorbable suture.
58. Completely withdraw the IV catheter from the thoracic cavity.
59. Close the abdominal skin incision using wound clips or 4-0 or 5-0 absorbable or non-absorbable suture.

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***This completes the surgery.***

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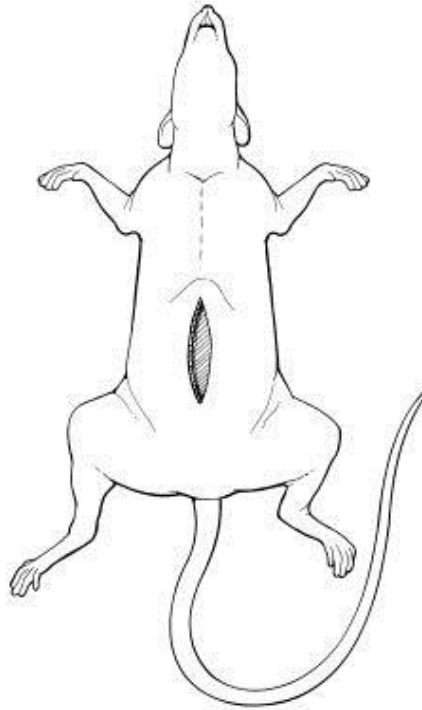


## ***Intrapleural Pressure***

When two pressure channels are present, the Channel 1 catheter will first be placed in the serosal layer overlapping the esophagus. The Channel 2 catheter will then be placed for systemic blood pressure followed by the biopotential leads, which will be routed subcutaneously to collect an ECG signal. The implant will be placed in the abdominal cavity. In most species, an 8 cm long catheter is recommended for use. Please refer to Appendix D for catheter configuration options.

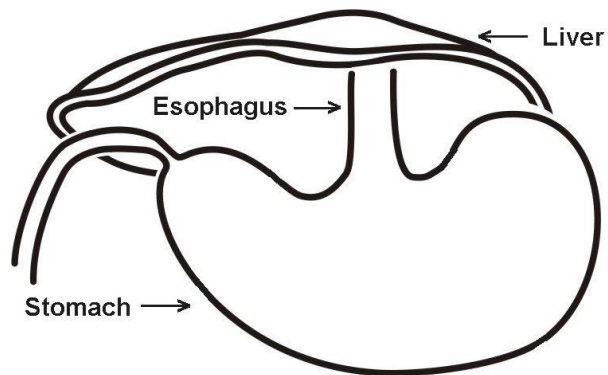
**Tissue hydration should be maintained throughout the procedure.**

1. Position the animal in dorsal recumbency on the surgery table with the feet closest to the surgeon. Provide supplemental warmth during surgery.
2. Loosely tape the animal's limbs to the table.
3. Establish a sterile field and apply sterile draping material.
4. Using a scalpel blade, make a 4-5 cm midline incision through the skin on the abdomen. The incision should extend cranially to the xyphoid process.
5. Use blunt dissection to gently separate the skin from the abdominal wall around the incision.
6. Using small surgical scissors make a 4-5 cm midline incision through the abdominal wall. The incision should extend cranially to the xyphoid process. Take care not to damage internal organs. (See Figure 32)



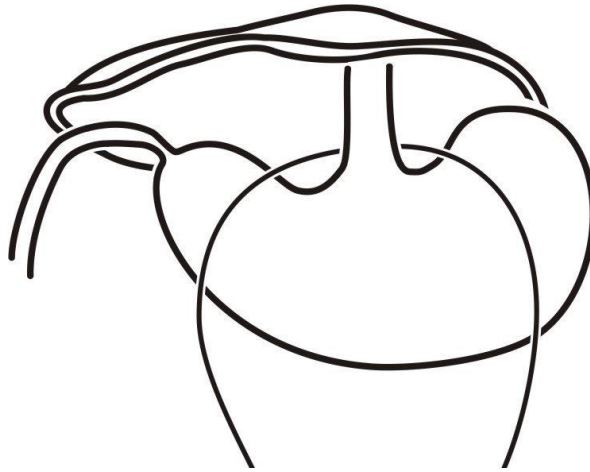
**Figure 32: Ventral abdominal incision**

7. Reflect the liver and surrounding intestines with saline moistened 2 x 2 cm gauze. The liver should stay reflected until the esophagus resumes normal position.
8. Identify the junction point where the esophagus enters the stomach. This is where the cannulation will take place. (See Figure 33)



**Figure 33: Identify cannulation site**

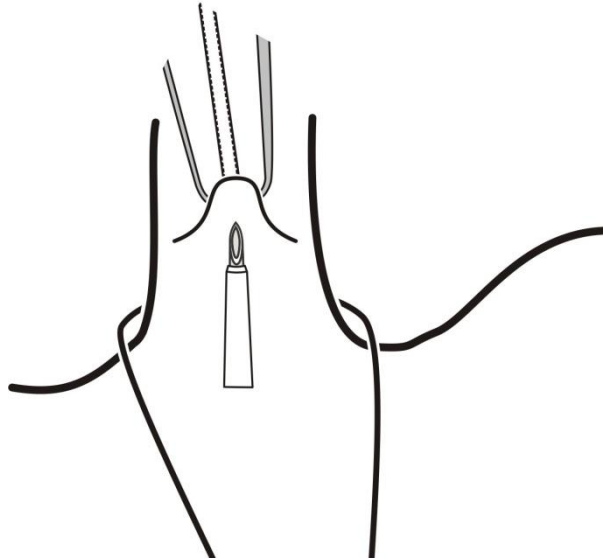
9. Carefully pass a pair of fine tipped, curved forceps under the esophagus at the junction point.
10. Carefully pass one piece of 5-0 suture underneath the esophagus. This suture will be used to temporarily retract the esophagus. (See Figure 34)



**Figure 34: Placement of suture**

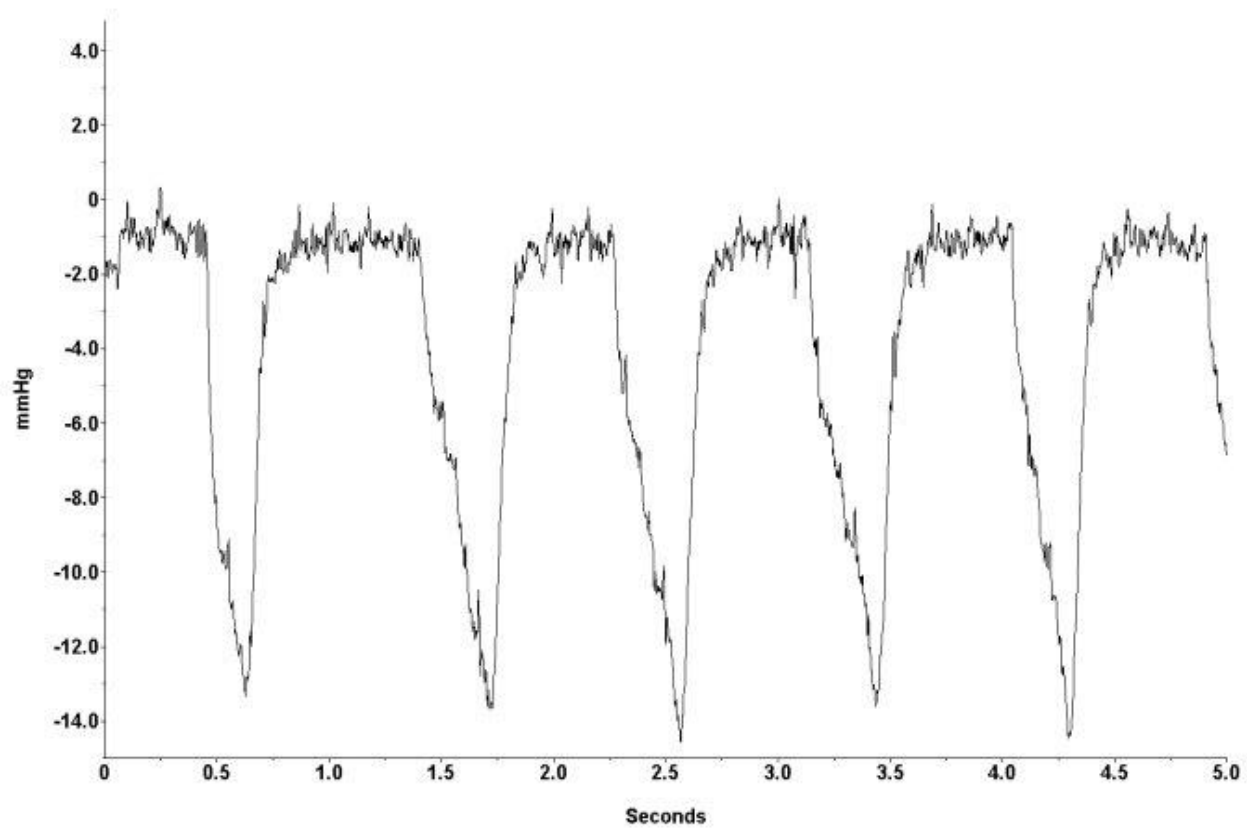
11. Remove the implant from the sterile package and transfer it to the sterile field. **Do not handle the implant by grasping the catheter. This may cause damage to the catheter or the pressure sensor. See the Preventing Damaged Sensors in Blood Pressure Implants technical note on [www.datasci.com](http://www.datasci.com).**
12. Turn the AM radio on and carefully remove the tip cover from the pleural pressure catheter (Channel 1 if HD-S21). Removal of the tip cover should be done by alternating gentle traction and release. **Take care to prevent gel loss due to compression of the catheter or sudden release of the tip cover. Always examine the catheter under high magnification prior to implantation for gel loss or bubbles. If there is gel loss or bubbles, the catheter will need to be re-gelled. For help with this process, refer to the Guidelines for the Re-gel of Small Animal Catheters on our website: [www.datasci.com](http://www.datasci.com)** A video clip of this procedure is also available on our website.
13. Gently apply tension to the suture around the esophagus using a hemostat. This will retract it for easier access and visibility.
14. Carefully grasp and lift up the serosal layer overlaying the esophagus with a pair of forceps. (See Figure 35)
15. Using a 20-gauge IV catheter with needle, incise the serosal layer of the esophagus just cranial to the retraction suture. Be careful not to advance the needle very far. (See Figure 35)





**Figure 35: Grab the serosal layer with a forceps and insert the needle**

16. Advance the IV catheter under the serosal layer and withdraw the needle. The IV catheter should be advanced approximately 3 cm or up to the catheter hub.
17. Completely withdraw the IV catheter and insert the pressure catheter by grasping the overlap section of the catheter using the vessel cannulation forceps.
18. Advance the pressure catheter approximately 3 cm.
19. Monitor the pleural pressure signal with the software system to verify proper placement. A desirable signal is one with no heart rate artifact. The catheter may have to be advanced or withdrawn slightly depending on the quality of the signal. (See Figure 36)



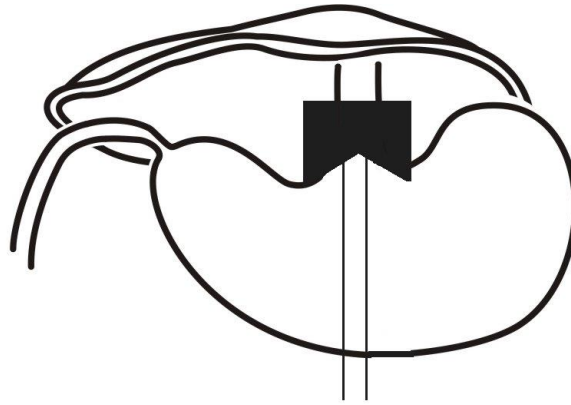
**Figure 36: Intrapleural pressure signal**

20. When the catheter is in the proper location, dry the entry site with cotton tip applicators and apply a very small amount of Vetbond tissue adhesive using gel-loading micropipette tips.
21. Once the Vetbond has visibly set, anchor the catheter in place with a small fiber patch. The patch can be prepared by cutting out a small 3 mm x 5 mm rectangle. Cut a wedge in the patch halfway across the width of the patch. (See Figure 37)



**Figure 37: Cut a wedge into the fiber patch**

22. Place the fiber patch across the catheter entry site with the catheter passing through the wedge. Secure the patch to the catheter and esophagus by applying a few drops of Vetbond tissue adhesive using the gel-loading micropipette tips. This will encourage connective tissue growth. (See Figure 38)



**Figure 38: Placement of the fiber patch**

23. Release the retraction suture and remove the suture from around the esophagus.
24. Remove the gauze from the abdominal cavity.
25. Irrigate the abdominal cavity with sterile saline.
26. Proceed to the section titled **Abdominal Aorta Cannulation with Intraperitoneal Cavity Device Placement**.



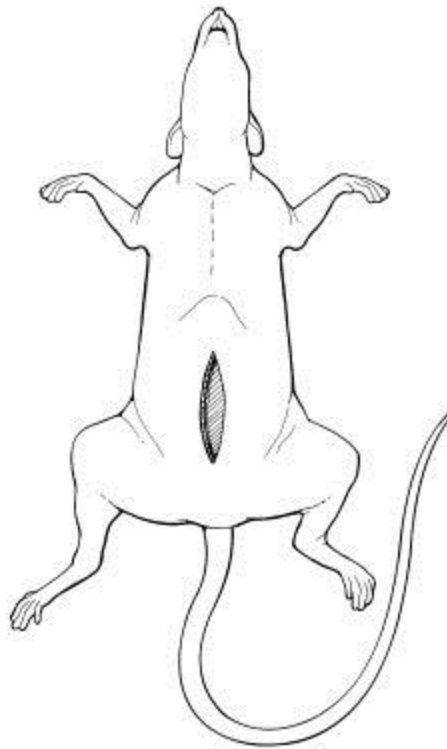
### ***Bladder Pressure***

When two pressure channels are present (HD-S21), the Channel 1 catheter will first be placed in the bladder. The Channel 2 catheter will then be placed for systemic blood pressure followed by the biopotential leads, which will be routed subcutaneously to collect an ECG signal. The implant will be placed in the abdominal cavity. In most species, an 8 cm long catheter with a 3 mm catheter tip is recommended for use. Please refer to Appendix D for catheter configuration options.

**Tissue hydration should be maintained throughout the procedure.**

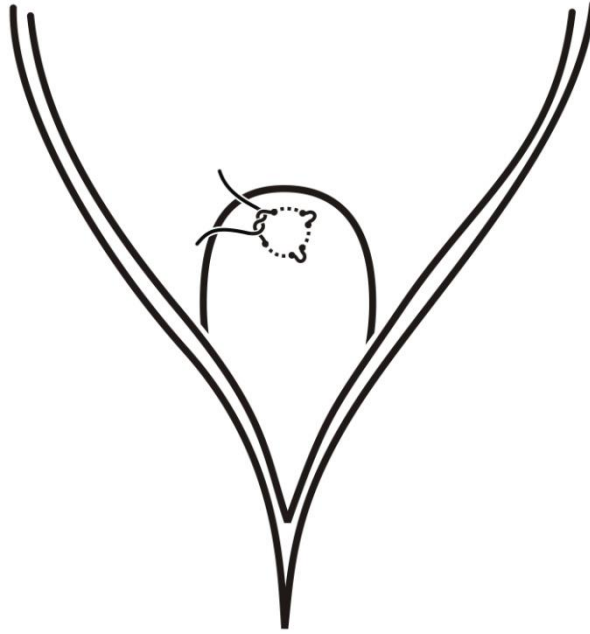
1. Position the animal in dorsal recumbency on the surgery table with the feet closest to the surgeon. Provide supplemental warmth during surgery.
2. Loosely tape the animal's limbs to the table.
3. Establish a sterile field and apply sterile draping material.

4. Using a scalpel blade, make a 4-5 cm midline incision through the skin on the abdomen. The incision should extend caudally to easily access the bladder.
5. Use blunt dissection to gently separate the skin from the abdominal wall around the incision.
6. Using small surgical scissors make a 4-5 cm midline incision through the abdominal wall. The incision should extend caudally to easily access the bladder. Take care not to damage internal organs. (See Figure 39)



**Figure 39: Ventral abdominal incision**

7. Locate the bladder and reflect the surrounding intestines and tissue with saline-moistened 2 x 2 cm gauze.
8. Identify the target area at the apex of the bladder and install a loose purse-string suture superficially through the bladder wall. This should be done using 6-0 non-absorbable suture (silk) with a taper point needle. **Using anything other than a taper point needle will damage the tissue.** The purse-string suture should be anchored in the wall 3 times. **Take care not to grasp the bladder.** (See Figure 40)



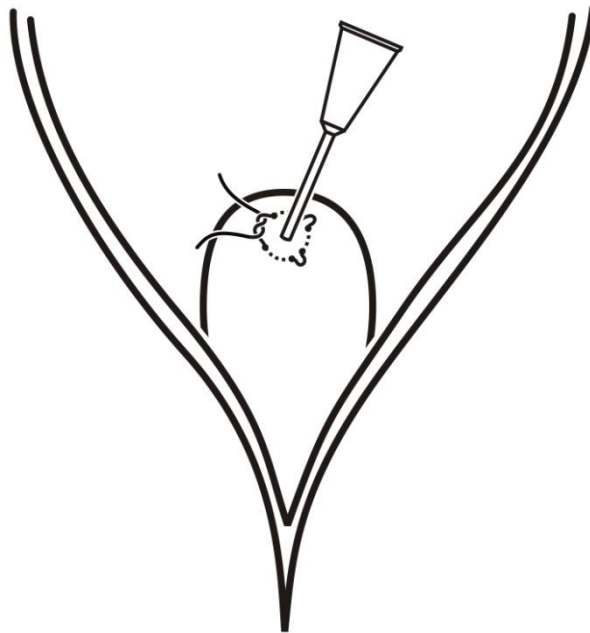
**Figure 40: Placement of the purse-string suture**

9. Remove the implant from the sterile package and transfer it to the sterile field. **Do not handle the implant by grasping the catheter. This may cause damage to the catheter or the pressure sensor. See the Preventing Damaged Sensors in Blood Pressure Implants technical note on [www.datasci.com](http://www.datasci.com).**
10. Turn the AM radio on and carefully remove the tip cover from the bladder pressure catheter (Channel 1 if HD-S21). Removal of the tip cover should be done by alternating gentle traction and release. **Take care to prevent gel loss due to compression of the catheter or sudden release of the tip cover. Always examine the catheter under high magnification prior to implantation for gel loss or bubbles. If there is gel loss or bubbles, the catheter will need to be re-gelled. For help with this process, refer to the Guidelines for the Re-gel of Small Animal Catheters on our website: [www.datasci.com](http://www.datasci.com)** A video clip of this procedure is also available on our website.
11. Tie a piece of non-absorbable suture around the suture aid on the catheter. (See Figure 41) The specific size of the suture is not critical but a color that is different from the purse-string suture may be helpful.



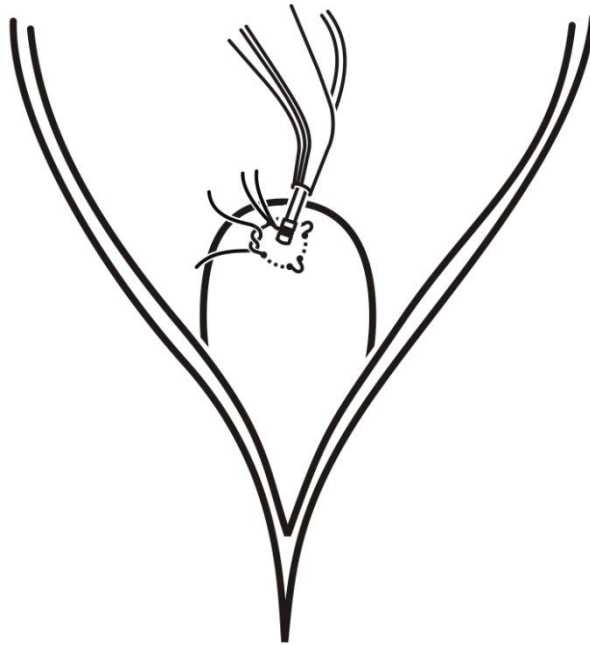
**Figure 41: Suture around the suture aid**

12. Puncture the bladder in the center of the purse-string suture using a 22-gauge needle. (See Figure 42)



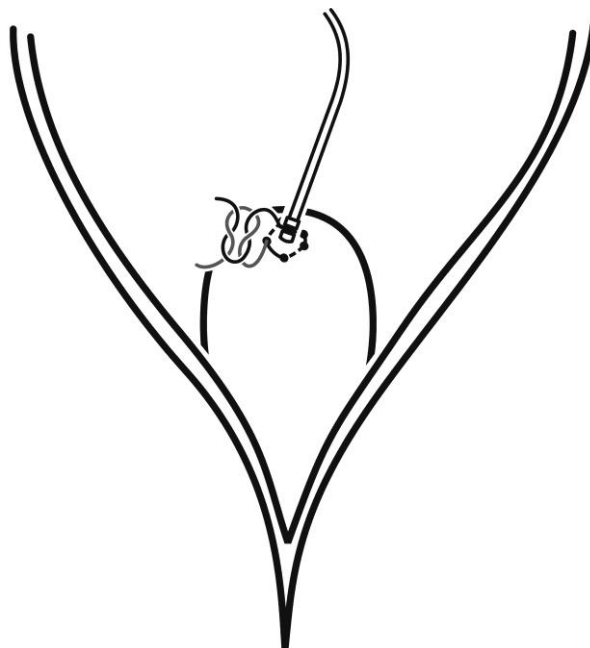
**Figure 42: Puncture the bladder wall**

13. Withdraw the needle and insert the pressure catheter by grasping the overlap section of the catheter using the vessel cannulation forceps.
14. Advance the catheter until the suture aid suture on the catheter is in direct contact with the bladder wall. (See Figure 43)



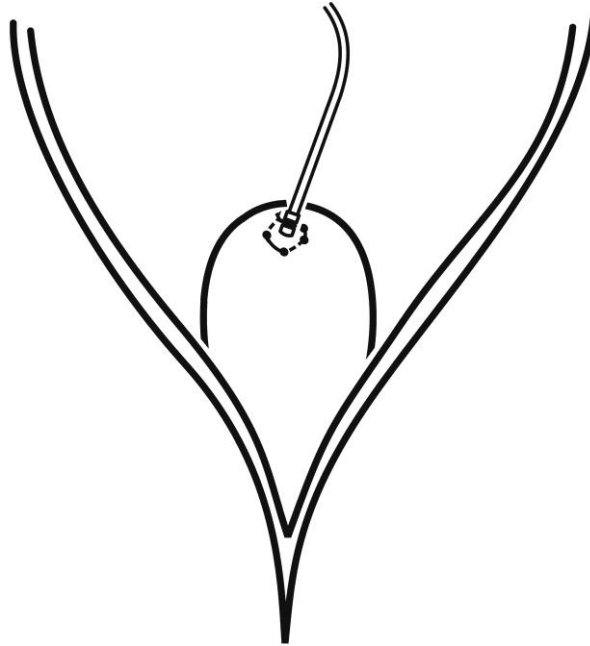
**Figure 43: Insertion of the catheter**

15. Gently draw the purse-string suture closed around the catheter.
16. Continue securing the purse-string suture with at least two more knots.
17. Tie one tail of the suture aid suture together with one tail of the purse-string suture and secure.  
(See Figure 44)



**Figure 44: Secure the suture tails**

18. Repeat the above step for the other two suture tails.
19. Cut the sutures as short as possible. (See Figure 45)



**Figure 45: Catheter tied in place**

20. Remove the gauze from the abdominal cavity.
21. Irrigate the abdominal cavity with sterile saline.
22. Proceed to the section titled **Abdominal Aorta Cannulation with Intraperitoneal Cavity Device Placement**.



### ***Intracavernosal Pressure***

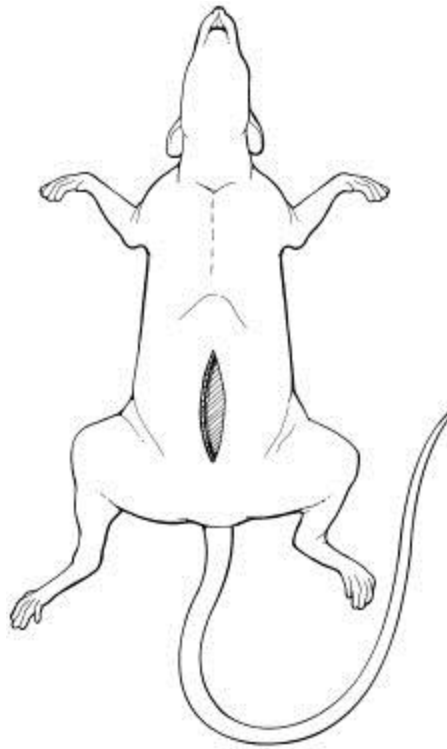
When two pressure channels are present, the Channel 1 catheter will first be placed in the corpus cavernosum of the penis. The Channel 2 catheter will then be placed for systemic blood pressure followed by the biopotential leads, which will be routed subcutaneously to collect an ECG signal. The



implant will be placed in the abdominal cavity. In most species, an 8 cm long catheter with 4.5 mm tip is recommended for use. Please refer to Appendix D for catheter configuration options.

**Tissue hydration should be maintained throughout the procedure.**

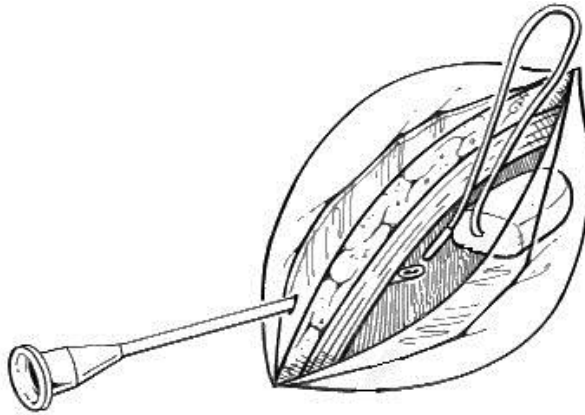
1. Position the animal in dorsal recumbency on the surgery table with the feet closest to the surgeon. Provide supplemental warmth during surgery.
2. Loosely tape the animal's limbs to the table.
3. Establish a sterile field and apply sterile draping material.
4. Using a scalpel blade, make a 4-5 cm midline incision through the skin on the abdomen.
5. Use blunt dissection to gently separate the skin from the abdominal wall around the incision.
6. Using small surgical scissors make a 4-5 cm midline incision through the abdominal wall. Take care not to damage internal organs. (See Figure 46)



**Figure 46: Ventral abdominal incision**

7. Using small surgical scissors make a 2 cm midline incision through the skin over the scrotal region.
8. Position the implant in the abdominal cavity with the catheter directed caudally.

9. Pass a 14-gauge needle through the abdominal cavity near the caudal aspect of the incision. Pass the needle from the outside of the incision into the abdominal cavity taking care not to damage any internal organs. (See Figure 47)

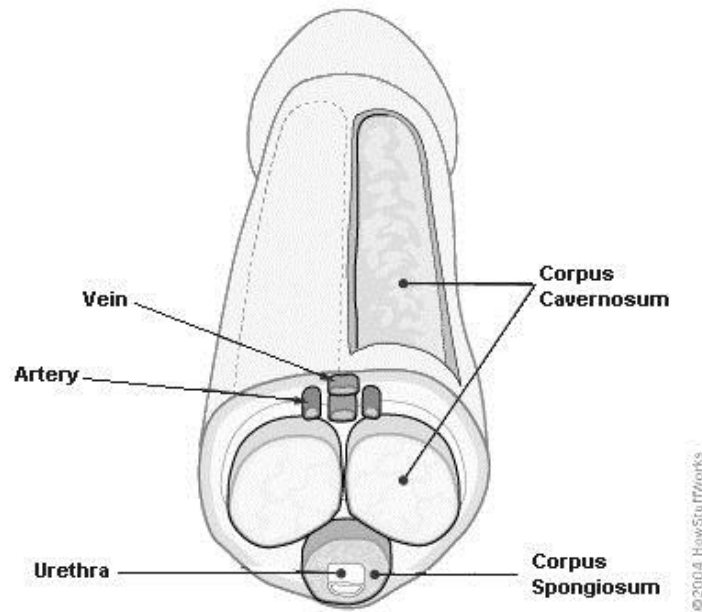


**Figure 47: Externalizing the catheter**

10. Insert the catheter into the lumen of the needle.
11. Withdraw the needle leaving the catheter exteriorized through the abdominal wall.
12. Using a metal trocar, tunnel subcutaneously from the scrotal incision to the abdominal incision.
13. Place the plastic sleeve over the metal trocar and remove the trocar leaving the sleeve in place.
14. Insert the catheter into the plastic sleeve.
15. Withdraw the plastic sleeve leaving the catheter in place. The tip of the catheter should now be exiting the scrotal incision.
16. Retract the prepuce cranially using either a hemostat or suturing it to the skin over the abdomen.
17. Remove a small area of fascia over the shaft of the penis.
18. Remove the implant from the sterile package and transfer it to the sterile field. **Do not handle the implant by grasping the catheter. This may cause damage to the catheter or the pressure sensor. See the Preventing Damaged Sensors in Blood Pressure Implants technical note on [www.datasci.com](http://www.datasci.com).**
19. Turn the AM radio on and carefully remove the tip cover from the intracavernosal pressure catheter (Channel 1 if HD-S21). Removal of the tip cover should be done by alternating gentle traction and release. **Take care to prevent gel loss due to compression of the catheter or sudden release of the tip cover. Always examine the catheter under high magnification prior to implantation for gel loss or bubbles. If there is gel loss or bubbles, the catheter will need to be re-gelled. For help with this process, refer to the Guidelines for the Re-gel**

of Small Animal Catheters on our website: [www.datasci.com](http://www.datasci.com) A video clip of this procedure is also available on our website.

20. Incise the shaft of the penis using a 20-gauge needle. Ensure the needle enters the corpus cavernosum. (See Figure 48)



**Figure 48: Anatomy of the penis**

21. Advance the needle approximately 5 mm.
22. Withdraw the needle and insert the pressure catheter by grasping the overlap section of the catheter using the vessel cannulation forceps.
23. Advance the catheter approximately 5 mm.
24. When the catheter is in the proper location, dry the entry site with cotton tip applicators and apply a very small amount of Vetbond tissue adhesive using gel-loading micropipette tips.
25. Once the Vetbond has visibly set, anchor the catheter in place with a small fiber patch. The patch can be prepared by cutting out a small 3 mm x 5 mm rectangle. Cut a wedge in the patch halfway across the width of the patch. (See Figure 49)



**Figure 49: Cut a wedge into the fiber patch**

26. Place the fiber patch across the catheter entry site with the catheter passing through the wedge. Secure the patch to the catheter and penile shaft by applying a few drops of Vetbond tissue adhesive using the gel-loading micropipette tips. This will encourage connective tissue growth.
27. In addition, secure the catheter stem to the surrounding tissue in a few different locations using 5-0 non-absorbable suture.
28. Irrigate the tissue with sterile saline.
29. Close the skin for the scrotal incision using 4-0 or 5-0 absorbable or non-absorbable suture.
30. Proceed to the section titled **Abdominal Aorta Cannulation with Intraperitoneal Cavity Device Placement**.



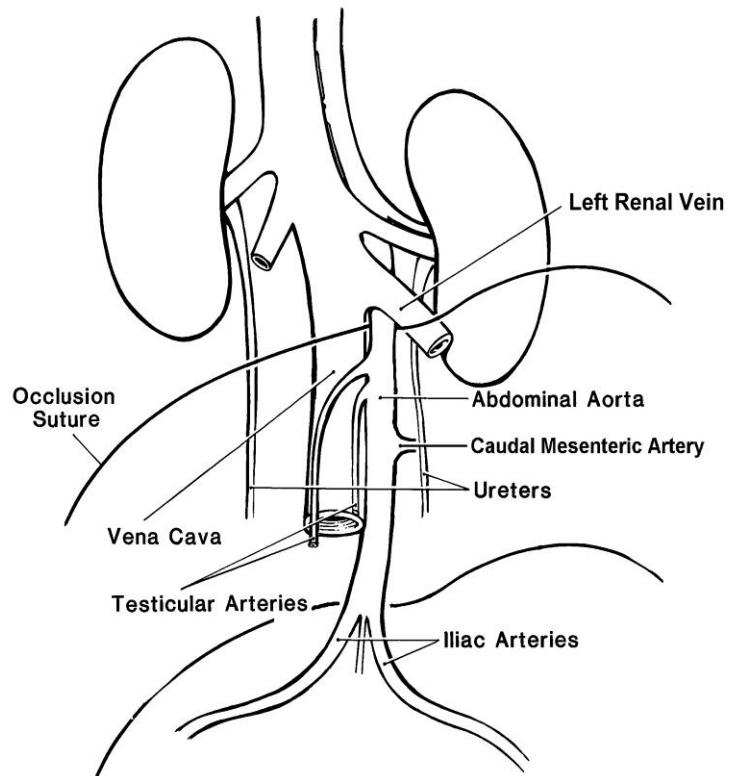
### ***Abdominal Aorta Cannulation with Intraperitoneal Cavity Device Placement***

The catheter will be placed in the abdominal aorta and positioned so that the sensing region of the catheter is between the renal arteries and the iliac bifurcation. The implant portion of the device is positioned inside the intraperitoneal cavity. The suture rib on the implant should be incorporated into the abdominal wall closure. If the abdominal aorta cannulation is performed together with another pressure-sensing application, a 10 cm long catheter is recommended for use in conjunction with LVP (not applicable to HD-S10), RVP, PAP or pleural pressure. An 8 cm long catheter is suitable in conjunction with bladder or intracavernosal pressure. Please refer to Appendix D for catheter configuration options.

#### ***Abdominal Aorta Cannulation (Tissue hydration should be maintained throughout the procedure.)***

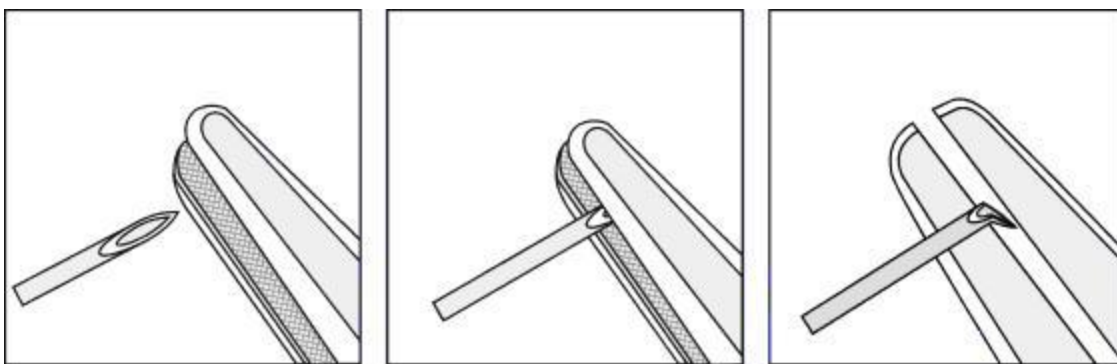
1. Remove any remaining items, such as retraction devices or gauze, from the abdominal cavity.
2. With sterile cotton tip applicators, gently manipulate the intestines cranial and lateral and locate the aorta. **The surgeon should be able to visualize the entire length of the abdominal aorta from the iliac bifurcation, cranially, to the crossover of the left renal vein.**

3. Retract the intestines using a sterile 4 in x 4 in gauze sponge to allow access to the abdominal aorta. To form the gauze sponge retractor:
  - a) Unfold the gauze pad once.
  - b) Cut in half along the fold.
  - c) Begin at the folded edge and tightly roll the gauze to the opposite edge.
  - d) Fold in half lengthwise.
  - e) Insert the gauze into the abdominal cavity with the open edge of the gauze closest to the intestines and the folded end toward the diaphragm.
4. Once the gauze sponge retractor is in place, thoroughly moisten the gauze with sterile saline.
5. Using sterile cotton tip applicators carefully separate the overlying tissue from the aorta surface just caudal to the crossover of the left renal vein and just cranial to the iliac bifurcation. The catheter entry site will be just cranial to the iliac bifurcation.
6. Using vessel dilators, carefully separate the aorta from the vena cava just caudal to the left renal vein. There is often a natural separation in between the vessels in this area where they can be more easily separated.
7. Carefully pass one piece of 4-0 or 5-0 suture between the vena cava and aorta so that the suture lies underneath the aorta. This suture will be used to temporarily occlude blood flow to allow introduction of the catheter into the vessel. (See Figure 50)
8. Using vessel dilators, carefully separate the aorta from the vena cava just cranial to the iliac bifurcation. Care should be taken to avoid puncturing the vena cava. In this area, a portion of the vena cava is situated underneath the aorta.
9. Carefully pass one piece of 4-0 or 5-0 suture between the vena cava and aorta so that the suture lies underneath the aorta. This suture will be used to temporarily occlude blood flow to allow introduction of the catheter into the vessel. (See Figure 50)



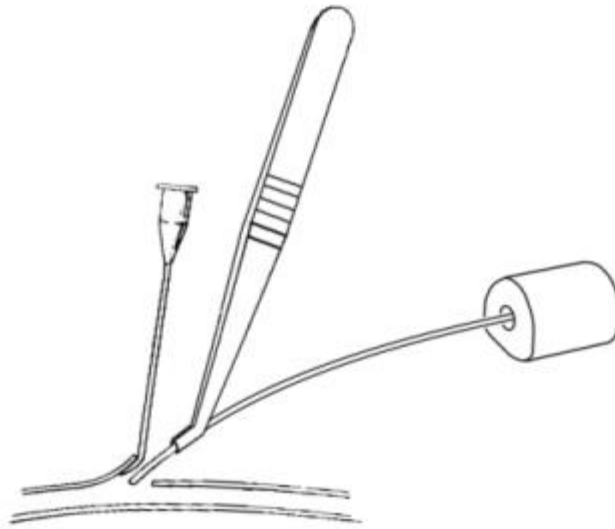
**Figure 50: Proper placement of the cranial and caudal occlusion sutures**

10. Prepare a catheter introducer by bending the beveled tip of a 22-gauge syringe needle. Hold the syringe needle with the beveled side facing up. Grasp just the beveled area of the needle with a needle holder and bend the tip downward to an angle of approximately 90°. (See Figure 51) The syringe needle may be placed onto a 1 cc syringe to be used as a handle to hold onto the needle and allow for a clear view of the surgical area.



**Figure 51: Needle bending technique**

11. Fill two gel-loading micropipette tips with Vetbond tissue adhesive and set aside. They will be used to dispense a very small amount of adhesive to seal the vessel.
  12. Remove the implant from the sterile package and transfer it to the sterile field. **Do not handle the implant by grasping the catheter. This may cause damage to the catheter or the pressure sensor. See the Preventing Damaged Sensors in Blood Pressure Implants technical note on [www.datasci.com](http://www.datasci.com).**
  13. Turn the AM radio on and carefully remove the tip cover. Removal of the tip cover should be done by alternating gentle traction and release. **Take care to prevent gel loss due to compression of the catheter or sudden release of the tip cover. Always examine the catheter under high magnification prior to implantation for gel loss or bubbles. If there is gel loss or bubbles, the catheter will need to be re-gelled. For help with this process, refer to the Guidelines for the Re-gel of Small Animal Catheters on our website: [www.datasci.com](http://www.datasci.com)** A video clip of this procedure is also available on our website.
- The process of inserting the catheter into the aorta is an intricate maneuver and needs to be performed quickly and efficiently in order to prevent hind limb ischemia.***
14. Apply one drop of 2% Lidocaine to the aorta to fully dilate it, if necessary.
  15. Grasp the overlap section of the catheter with a pair of Vessel Cannulation Forceps.
  16. Gently apply tension to both of the occlusion sutures using a hemostat. This will temporarily occlude blood flow in the aorta.
  17. Using the 22-gauge needle as a catheter introducer, pierce the artery 1-2 mm cranial to the iliac bifurcation and insert the catheter upstream toward the heart. (See Figure 52) Once the catheter is inserted into the vessel, withdraw the catheter introducer.



**Figure 52: Vessel cannulation technique**

18. Advance the catheter cranially so that the entire thin-walled section is within the vessel. Maximizing the amount of catheter that is inserted will allow for more re-uses of the implant. **Do not advance the catheter past the cranial occlusion suture.** (See Figure 54)
19. Dry the aorta at the catheter entry site with cotton tip applicators and apply a very small amount of Vetbond tissue adhesive using the gel-loading micropipette tips. **If the area is not dried effectively, there will be poor bonding of the tissue adhesive, resulting in leakage.**
20. Once the Vetbond has visibly set, slowly release the tension on both of the occlusion sutures and observe the catheter entry site for leakage. If leakage is observed, re-occlude the vessel, clear the site of blood and apply only enough additional Vetbond to seal the leak.
21. Once hemostasis is achieved, apply one drop of 2% Lidocaine to the aorta to help relieve vessel spasms.
22. If using the HD-S21 or HD-S11, verify proper catheter placement by turning the AM radio on and bringing it close to the implant. A rapidly fluctuating tone corresponding with the cardiac cycle indicates a properly placed catheter. If the radio tone is not fluctuating, the catheter is not properly placed and has likely been placed either into the vena cava or within the tissue surrounding the aorta. Verification can also be done by monitoring the live signal via a telemetry system in the surgical suite. **PLEASE NOTE: if the HD-S10 is being used, no tone fluctuation will be audible via the radio. This is normal and expected.** Placement may still be verified by the live signal collected with the telemetry system in the surgical suite.
23. Cut the caudal occlusion suture close to the aorta and carefully remove the suture remnant from beneath the aorta.

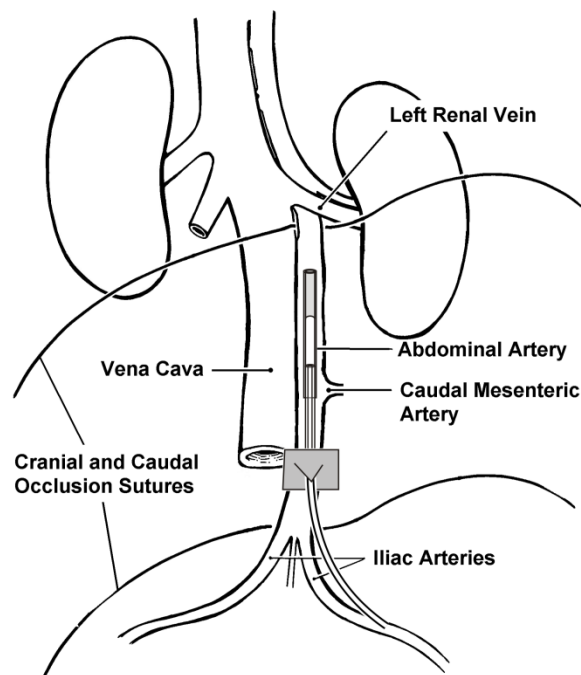


24. Anchor the catheter in place with a small fiber patch. The patch can be prepared by cutting out a small 3 mm x 5 mm rectangle. Cut a wedge in the patch halfway across the width of the patch. (See Figure 53)



**Figure 53: Cut a wedge into the fiber patch**

25. Place the fiber patch across the catheter entry site with the catheter passing through the wedge. Secure the patch to the catheter, vessel, and surrounding tissues by applying a few drops of Vetbond tissue adhesive using the gel-loading micropipette tips. (See Figure 54)

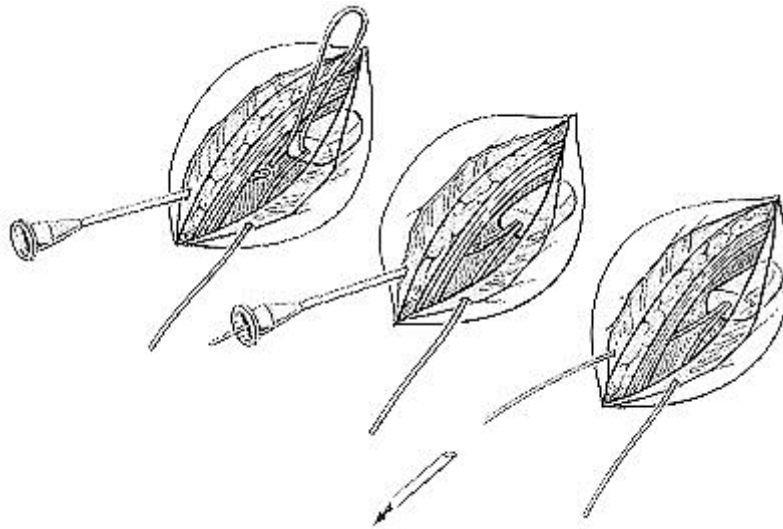


**Figure 54: Catheter in place in the aorta (occlusion sutures shown for reference)**

26. Cut the cranial occlusion suture close to the aorta and carefully remove the suture remnant from beneath the aorta.

## Device Placement

1. Carefully remove the gauze sponge retraction taking care not to dislodge the catheter.
2. Irrigate the peritoneal cavity with warm, sterile saline. Gently massage the intestines back into place.
3. Place the implant on top of the intestines and position the implant parallel to the long axis of the body. If any catheter was placed to collect LV, RV, PA, or intrapleural pressure, the catheter(s) should be directed cranially and the suture rib directed ventrally. If any catheter was placed to collect abdominal aorta, bladder, or intracavernosal pressure, the catheter(s) should be directed caudally and the suture rib directed ventrally.
4. Pass a 14-gauge needle through the abdominal wall near the left lateral caudal aspect of the incision. Pass the needle from the outside of the incision into the abdominal cavity taking care not to damage any internal organs. (See Figure 55)
5. Insert the positive lead (red tubing) through the lumen of the needle and out of the abdomen.
6. Withdraw the needle leaving the lead externalized.
7. Repeat steps 4 through 7 with the negative lead (clear tubing) exiting the abdominal cavity on the right lateral side. (See Figure 55)



**Figure 55: Externalizing the ECG Leads**

8. Close the abdominal wall using 4-0 or 5-0 non-absorbable suture with a simple interrupted pattern. Incorporate the suture rib on the implant into the closure.
9. Proceed to the section titled **Placement of ECG Leads**.



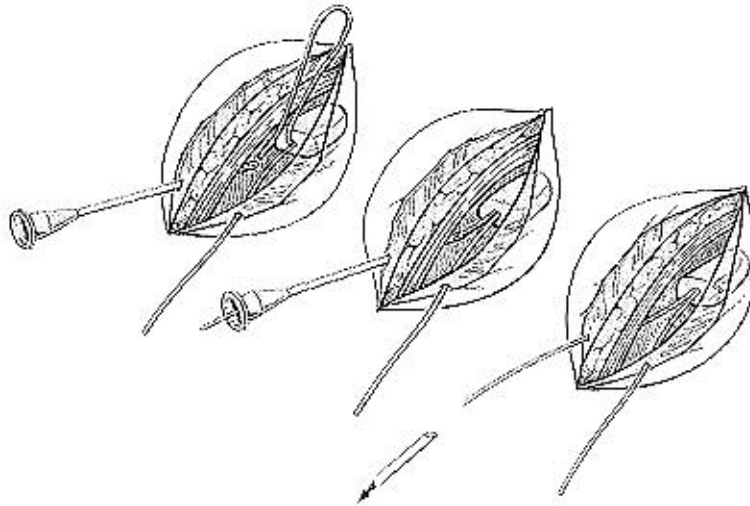
## ***Femoral Artery Cannulation With Intraperitoneal Device Placement***

The catheter will be placed in the femoral artery and positioned so that the sensing region of the catheter is in the descending aorta. The transmitter portion of the device is ideally positioned in the abdominal cavity. In most species, a 10 cm long catheter is recommended for use. Please refer to Appendix D for catheter configuration options.

### **Device Placement (*Tissue hydration should be maintained throughout the procedure.*)**

1. Position the animal in dorsal recumbency on the surgery table. Provide supplemental warmth during the surgery.
2. Loosely tape the animal's limbs to the table.
3. Establish a sterile surgical field and apply sterile draping material.
4. Using a scalpel blade, make a 2-3 cm midline incision through the skin on the ventral abdomen.
5. Using small surgical scissors or a scalpel blade, make a 2-3 cm midline incision through the abdominal wall.
6. Using small surgical scissors, make a 1.5 cm midline incision through the skin over the femoral vessels.
7. Remove the transmitter from the sterile package and transfer it to the sterile field. **Do not handle the transmitter by grasping the catheter. This may cause damage to the catheter or the pressure sensor.**
8. Place the transmitter on top of the intestines, parallel to the long axis of the body with the catheter oriented caudally.
9. Pass a 20-gauge needle from the inside of the femoral incision into the abdominal cavity taking care not to damage any internal organs.
10. Insert the catheter through the lumen of the needle and out of the abdomen.
11. Withdraw the needle leaving the catheter positioned within the femoral incision.
12. Pass a 14-gauge needle through the abdominal wall near the left lateral caudal aspect of the incision. Pass the needle from the outside of the incision into the abdominal cavity taking care not to damage any internal organs. (See Figure 10)
13. Insert the positive lead (red tubing) through the lumen of the needle and out of the abdomen.
14. Withdraw the needle leaving the lead externalized.

15. Repeat steps 12 through 14 with the negative lead (clear tubing) exiting the abdominal cavity on the right lateral side. (See Figure 56)

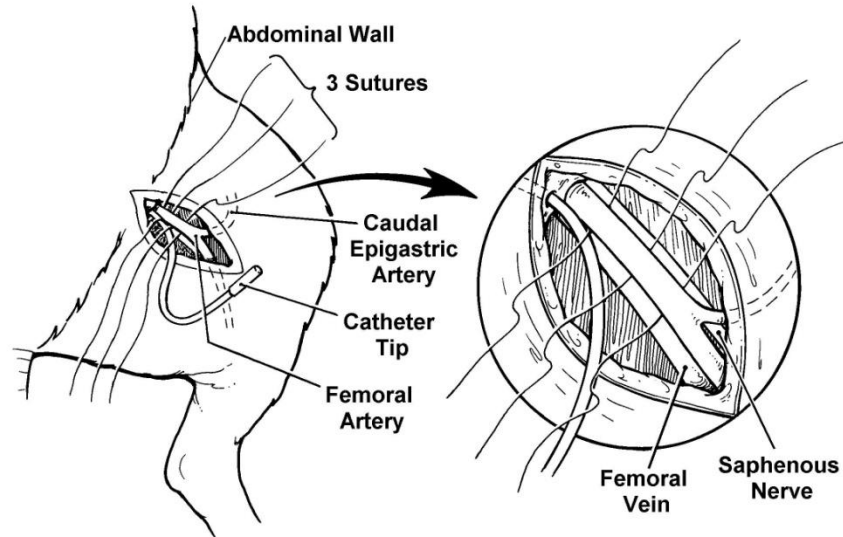


**Figure 56: Externalizing the ECG Leads**

16. Irrigate the peritoneal cavity with warm, sterile saline.
17. Close the abdominal wall using 4-0 or 5-0 non-absorbable suture with a simple interrupted pattern. Incorporate the suture rib on the transmitter into the closure.

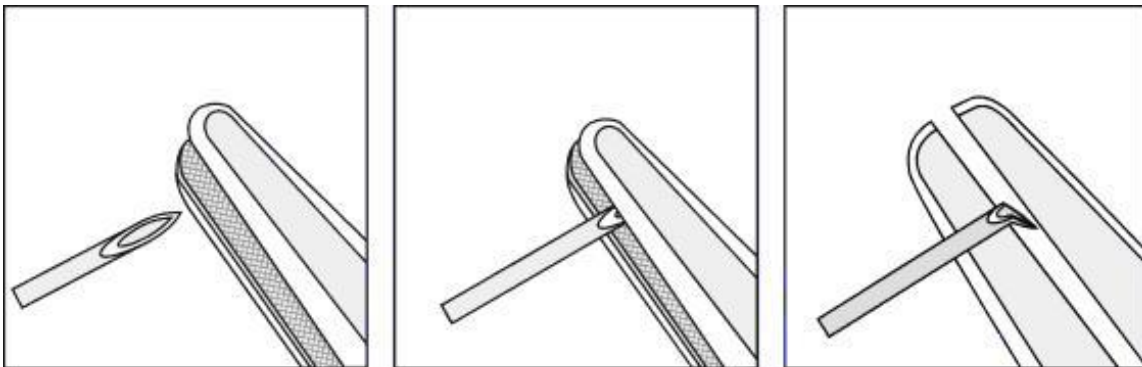
**Femoral Cannulation (*Tissue hydration should be maintained throughout the procedure.*)**

1. Carefully locate and expose the femoral vessels. They are bundled together with the saphenous nerve and can be found between the abdominal wall and the branching point of the caudal epigastric artery and vein.
2. Using fine tipped, curved forceps, carefully isolate at least 10 mm of the femoral artery from the femoral vein and saphenous nerve.
3. Pass three pieces of 4-0 or 5-0 non-absorbable suture underneath the isolated artery section. The furthest distal suture will be used to permanently ligate the femoral artery while the suture closer to the abdominal wall will be used to temporarily occlude blood flow to allow for placement of the catheter. The middle suture will be used to hold the catheter in place after cannulation of the artery. (See Figure 57)



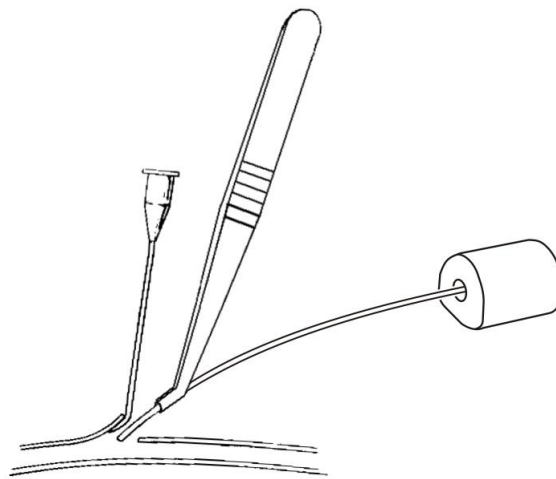
**Figure 57: Femoral artery isolated with occlusion sutures in place**

4. Apply a few drops of 2% Lidocaine to the femoral artery. This will help dilate the vessel and help prevent vasospasms.
5. Prepare a catheter introducer by bending the beveled tip of a 20-gauge syringe needle. Hold the syringe needle with the beveled side facing up. Grasp just the beveled area of the needle with a needle holder and bend the tip downward to an angle of approximately 90°. (See Figure 58) The syringe needle may be placed onto a 1 cc syringe to be used as a handle to hold onto the needle and allow for a clear view of the surgical area.



**Figure 58: Needle bending technique**

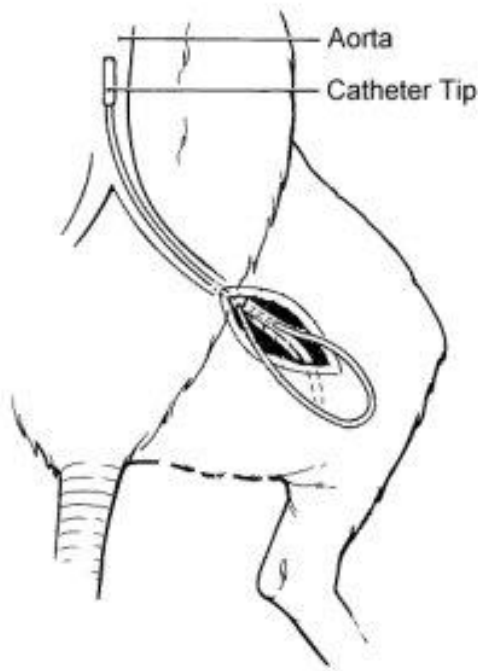
6. Turn the AM radio on and carefully remove the tip cover. Removal of the tip cover should be done by alternating gentle traction and release. **Take care to prevent gel loss due to compression of the catheter or sudden release of the tip cover. Always examine the catheter under high magnification before implantation for gel loss or bubbles. If there is gel loss or bubbles, the catheter will need to be re-gelled. For help with this process, refer to the Guidelines for the Re-gel of the PA-C40, C50-PXT, HD-S21, HD-S11, and HD-S10 Transmitters on our website: [www.datasci.com](http://www.datasci.com). A video clip of this procedure is also available on our website.**
7. Position the ligation suture as far distal as possible. Tie a secure knot around the artery to ligate the vessel and tape the suture tails to the surgery table.
8. Make a loose knot in both the occlusion suture and the middle suture and position them as close to the abdominal wall as possible.
9. Gently apply tension to the occlusion suture closest to the abdominal wall using a hemostat. This will elevate the artery and occlude blood flow. **Caution: Excessive tension can damage the artery.**
10. Grasp the tip of the catheter just distal to the thin-walled section using a Vessel Cannulation Forceps.
11. Using the 20-gauge needle as an introducer, pierce the artery just proximal to the ligation suture and insert the catheter upstream toward the aorta. (See Figure 59) While inserting the catheter into the vessel, withdraw the catheter introducer. **The catheter and catheter introducer may not fit inside the vessel together at the same time.**



**Figure 59: Vessel cannulation technique**

12. Advance the catheter into the artery until it reaches the occlusion suture.

13. Position the middle suture around the artery and catheter. Secure the catheter by pulling the suture tails to tighten the knot. **Releasing the catheter before it is secured may cause it to come out of the vessel.**
14. Once the catheter is secured, release the tension on the occlusion suture and advance the catheter beyond the suture into the abdominal cavity.
15. Continue to advance the catheter so that at least 1 cm of the sensing region of the catheter is positioned in the aorta cranial to the iliac bifurcation. (See Figure 60) Depending on the rat strain and weight, the catheter may have to be advanced to different lengths to reach the aorta. It is recommended before any survival surgery is performed, to verify the catheter tip placement for each strain of rat to be implanted. This can be done by performing a laparotomy on a cannulated, euthanized animal and locating the catheter in the aorta. Measurements can be taken to determine the appropriate length to insert the catheter.



**Figure 60: Optimal catheter placement in the aorta**

16. Tighten the occlusion suture and the middle suture around the artery and catheter to seal the artery wall around the catheter stem.
17. Release the tension on the ligation suture and tie the loose ends around the catheter stem to help anchor it in place.
18. Trim all suture tails as short as possible.
19. Close the skin incision with wound clips or 4-0 or 5-0 absorbable or non-absorbable suture.
20. Proceed to the section titled **Placement of ECG Leads.**



## ***Femoral Artery Cannulation With Subcutaneous Device Placement***

The catheter will be placed in the femoral artery and positioned so that the sensing region of the catheter is in the descending aorta. The transmitter portion of the device is ideally positioned along the lateral flank between the forelimb and hind limb. A subcutaneous pocket is formed by blunt dissection from the femoral incision up along the animal's flank. In most species, an 8 cm long catheter is recommended for use. Please refer Appendix D for catheter configuration options.

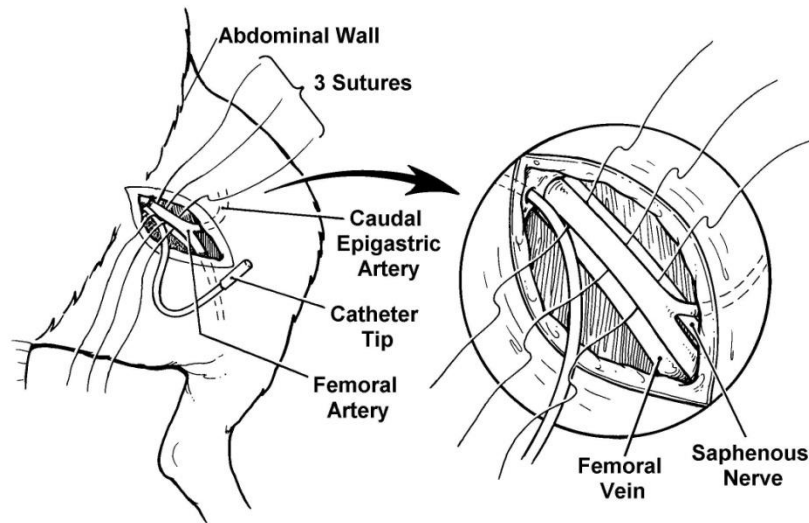
If core body temperature is desired, the transmitter should not be placed subcutaneously.

### **Femoral Cannulation (*Tissue hydration should be maintained throughout the procedure.*)**

1. Position the animal in dorsal recumbency on the surgery table. Provide supplemental warmth during the surgery.
2. Loosely tape the animal's limbs to the table.
3. Establish a sterile surgical field and apply sterile draping material.
4. Using small surgical scissors, make a 1.5 cm midline incision through the skin over the femoral vessels.
5. Carefully locate and expose the femoral vessels. They are bundled together with the saphenous nerve and can be found between the abdominal wall and the branching point of the caudal epigastric artery and vein.
6. Using fine tipped, curved forceps, carefully isolate at least 10 mm of the femoral artery from the femoral vein and saphenous nerve.

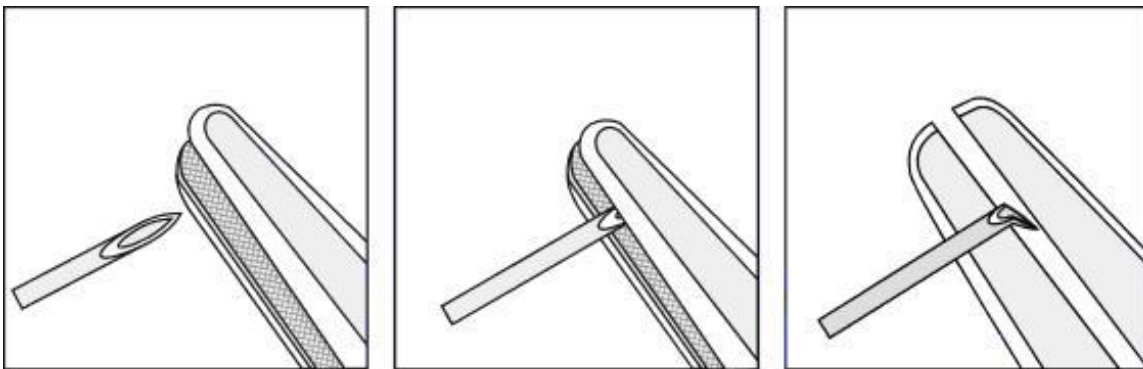


7. Pass three pieces of 4-0 or 5-0 non-absorbable suture underneath the isolated artery section. The furthest distal suture will be used to permanently ligate the femoral artery while the suture closer to the abdominal wall will be used to temporarily occlude blood flow to allow for placement of the catheter. The middle suture will be used to hold the catheter in place after cannulation of the artery. (See Figure 61)



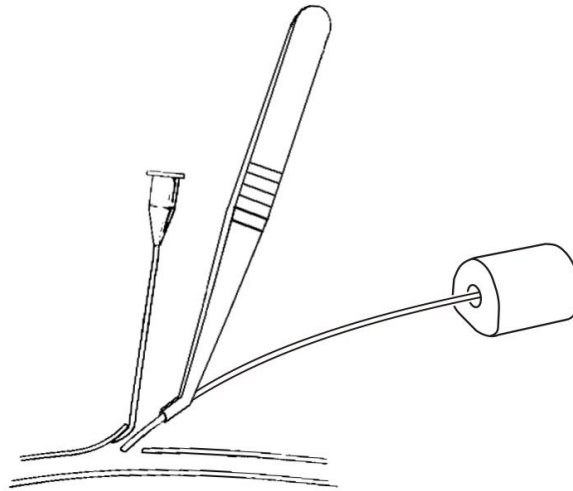
**Figure 61: Femoral artery isolated with occlusion sutures in place**

8. Apply a few drops of 2% Lidocaine to the femoral artery. This will help dilate the vessel and help prevent vasospasms.
9. Prepare a catheter introducer by bending the beveled tip of a 20-gauge syringe needle. Hold the syringe needle with the beveled side facing up. Grasp just the beveled area of the needle with a needle holder and bend the tip downward to an angle of approximately 90°. (See Figure 62) The syringe needle may be placed onto a 1 cc syringe to be used as a handle to hold onto the needle and allow for a clear view of the surgical area.



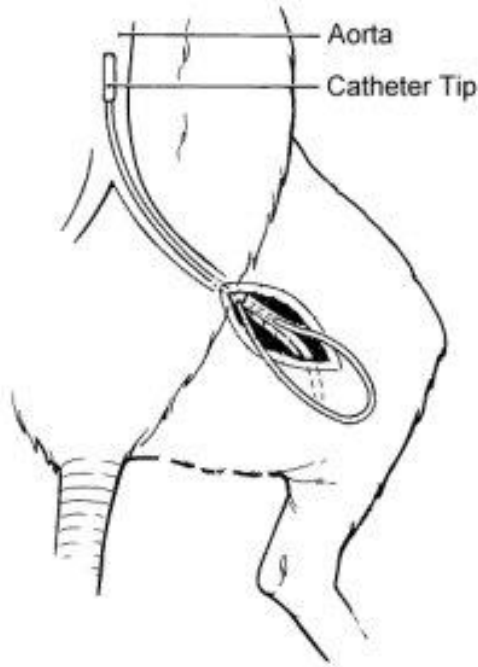
**Figure 62: Needle bending technique**

10. Remove the transmitter from the sterile package and transfer it to the sterile field. **Do not handle the transmitter by grasping the catheter. This may cause damage to the catheter or the pressure sensor.**
11. Turn the AM radio on and carefully remove the tip cover. Removal of the tip cover should be done by alternating gentle traction and release. **Take care to prevent gel loss due to compression of the catheter or sudden release of the tip cover. Always examine the catheter under high magnification before implantation for gel loss or bubbles. If there is gel loss or bubbles, the catheter will need to be re-gelled. For help with this process, refer to the Guidelines for the Re-gel of the PA-C40, C50-PXT, HD-S21, HD-S11, and HD-S10 Transmitters on our website: [www.datasci.com](http://www.datasci.com). A video clip of this procedure is also available on our website.**
12. Position the ligation suture as far distal as possible. Tie a secure knot around the artery to ligate the vessel and tape the suture tails to the surgery table.
13. Make a loose knot in both the occlusion suture and the middle suture and position them as close to the abdominal wall as possible.
14. Gently apply tension to the occlusion suture closest to the abdominal wall using a hemostat. This will elevate the artery and occlude blood flow. **Caution: Excessive tension can damage the artery.**
15. Grasp the tip of the catheter just distal to the thin-walled section using a Vessel Cannulation Forceps.
16. Using the 20-gauge needle as an introducer, pierce the artery just proximal to the ligation suture and insert the catheter upstream toward the aorta. (See Figure 63) While inserting the catheter into the vessel, withdraw the catheter introducer. **The catheter and catheter introducer may not fit inside the vessel together at the same time.**



**Figure 63: Vessel cannulation technique**

17. Advance the catheter into the artery until it reaches the occlusion suture.
18. Position the middle suture around the artery and catheter. Secure the catheter by pulling the suture tails to tighten the knot. **Releasing the catheter before it is secured may cause it to come out of the vessel.**
19. Once the catheter is secured, release the tension on the occlusion suture and advance the catheter beyond the suture into the abdominal cavity.
20. Continue to advance the catheter so that at least 1 cm of the sensing region of the catheter is positioned in the aorta cranial to the iliac bifurcation. (See Figure 64) Depending on the rat strain and weight, the catheter may have to be advanced to different lengths to reach the aorta. It is recommended before any survival surgery is performed, to verify the catheter tip placement for each strain of rat to be implanted. This can be done by performing a laparotomy on a cannulated, euthanized animal and locating the catheter in the aorta. Measurements can be taken to determine the appropriate length to insert the catheter.



**Figure 64: Optimal catheter placement in the aorta**

21. Tighten the occlusion suture and the middle suture around the artery and catheter to seal the artery wall around the catheter stem.
22. Release the tension on the ligation suture and tie the loose ends around the catheter stem to help anchor it in place.
23. Trim all suture tails as short as possible.
- 24.

**Device Placement (*Tissue hydration should be maintained throughout the procedure.*)**

1. Form a subcutaneous pocket by using blunt dissection. The pocket should be made along the lateral flank toward the caudal edge of the rib cage. **Ensure the pocket size is adequate for the type of transmitter being implanted. Making the pocket too small will result in tissue necrosis.**
2. Once the pocket is formed, irrigate the pocket with warm, sterile saline and insert the transmitter. The suture rib should be placed against the body and the rounded side should be toward the skin.
3. Close the subcutaneous pocket around the transmitter by placing suture in a purse-string pattern through the hypodermis and the muscle on the leg. This will help reduce seroma formation.

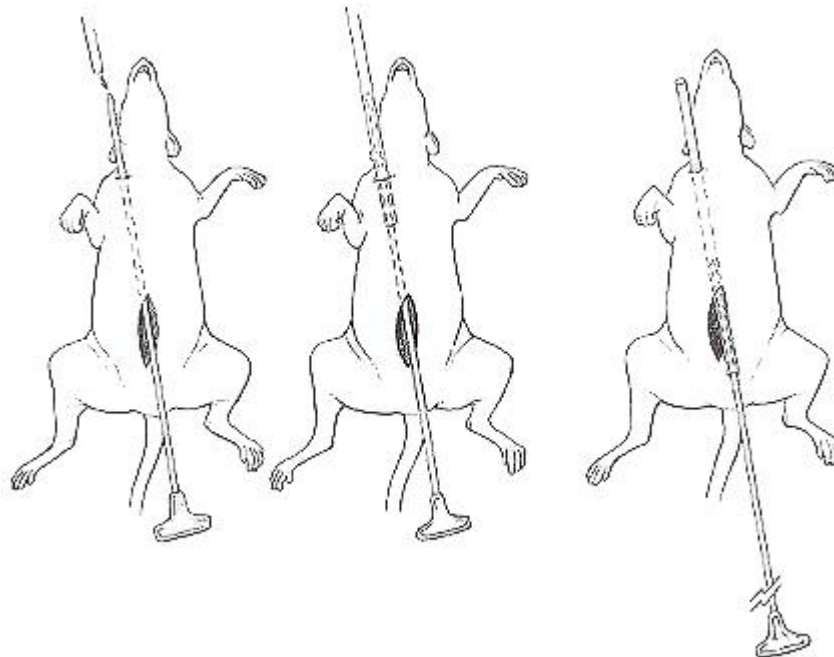
Proceed to the section titled **Placement of ECG Leads.**



## ***Placement of ECG Leads***

The biopotential leads are tunneled under the skin in a Modified Lead II placement.

1. Using small surgical scissors or a scalpel blade, make a small skin incision at each location where an ECG electrode will be placed; in this case one over the right pectoral muscle and one at the left caudal rib region approximately 2 cm to the left of the xyphoid process. (If the biopotential leads are coming from the abdominal cavity, the midline skin incision may be extended to the xyphoid process and blunt dissection may be used to separate the skin and muscle near the left caudal rib region instead of making another incision.)
2. Using the metal trocar, tunnel subcutaneously from the abdominal or femoral incision to the right pectoral muscle.
3. Place the plastic sleeve over the metal trocar and remove the trocar leaving the sleeve in place.
4. Place the negative lead (clear tubing) in the plastic sleeve and advance it at least 3 cm.
5. Withdraw the plastic sleeve leaving the lead in place. The end of the lead should now be exiting the chest incision. (See Figure 65)



**Figure 65: Subcutaneous Tunneling of the ECG Lead**

6. Shorten the lead material to the appropriate length with a pair of scissors. A small amount of lead may either be coiled under the skin or left in the abdominal cavity to account for growth of the animal and re-use of the implant. However, too much lead material could result in skin necrosis or strangling of the intestines.
7. Cut around the silicone tubing at the tip of the lead using a sharp sterile scalpel blade and remove approximately 1 cm of the silicone tubing to expose the stainless steel wire. This portion of silicone tubing should be completely removed from the lead.
8. Place a pre-made tip cover onto the end of the exposed wire and rotate it counter-clockwise until it is firmly attached to the wire. If pre-made tip covers are not available, they can be made by using the excess silicone tubing. After the silicone tubing is cut (Step 7), pull it to the end of the lead but do not remove it from the lead. Tie a piece of 4-0 or 5-0 non-absorbable suture around the silicone tubing and lead to secure the tubing in place. Cut off the excess silicone tubing that extends past the lead as this is not needed. (See Figure 66)
9. Place another suture around the silicone tubing just proximal to the exposed portion of the wire. This will inhibit fluids from migrating along the interior of the lead. (See Figure 66)



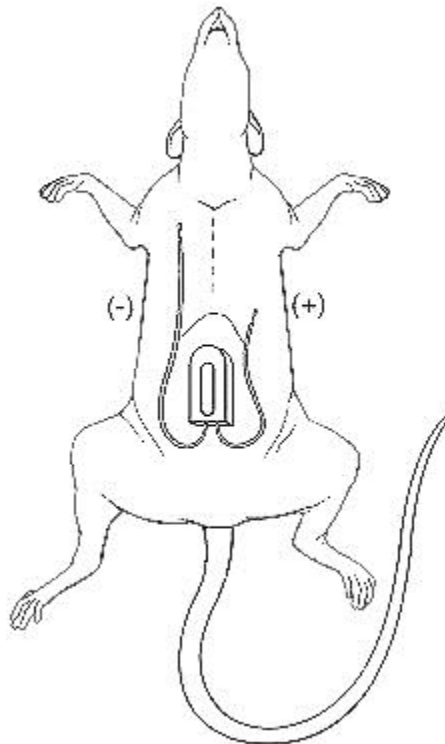
**Figure 66: ECG Lead**

10. Anchor the exposed portion of the lead to the muscle. This can be accomplished in two different ways:
  - a) Insert a needle with suture attached (4-0 or 5-0 non-absorbable) through a small portion of muscle on one side of the lead. Cross over the top of the exposed wire and insert the needle through a small portion of muscle on the other side of the lead. Tie the suture together thus drawing the muscle together over the top of the exposed portion of the lead. Another suture may be needed to cover the remaining exposed wire.
  - b) Using a 20-gauge syringe needle, tunnel through approximately 8 mm of muscle tissue so the needle passes through and exits the muscle. Insert the tip of the lead into the lumen of the needle until it cannot be advanced further. Withdraw the needle leaving the lead embedded in the muscle. **Do not place a tip cover on the lead until it has been embedded in the muscle.** (See Figure 67)



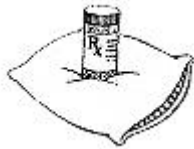
**Figure 67: Lead Tunneled Through Muscle**

11. Repeat the above steps for the positive lead (red tubing). This lead is positioned approximately 2 cm to the left of the xyphoid process. (See Figure 68)



**Figure 68: Modified Lead II Configuration**

12. Ensure both leads are lying flat against the muscle for the whole length of the lead. This will avoid irritation of the tissue.
13. Close all skin incisions using wound clips or 4-0 or 5-0 absorbable or non-absorbable suture.



### **Surgical Recovery**

1. Discontinue surgical anesthesia.
2. Maintain supplemental warmth throughout the anesthetic recovery.
3. Administer post-surgical analgesia.
4. Monitor animal closely for the return of normal postures and behaviors.

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***This completes the surgery.***

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# Appendix A: Device Care and Use

For information on device explantation, cleaning, storage, re-sterilization, re-gelling and more, please refer to the Technical Notes section on our website, [www.datasci.com](http://www.datasci.com) or contact Technical Services at [support@datasci.com](mailto:support@datasci.com).

Please refer to the DSI Implantable Telemetry System Manual (007678-003) for detailed information on any HD-S device or on the DSI website, [www.datasci.com](http://www.datasci.com).

## Operational Modes

HD-S implantable devices are equipped with two operational modes: ON, and OFF.

Implants are shipped to you in the OFF mode. The battery in the implant is not activated. When switched to ON, the implants begin to sense and transmit data. The switch to change between these two modes is in the interior of each implant and is therefore not visible. The switch is magnetically activated.

To switch operational modes:

1. Power on an AM radio and tune it to 550 kHz (the low end of the AM band).
2. Bring the radio close to the packaged implant.

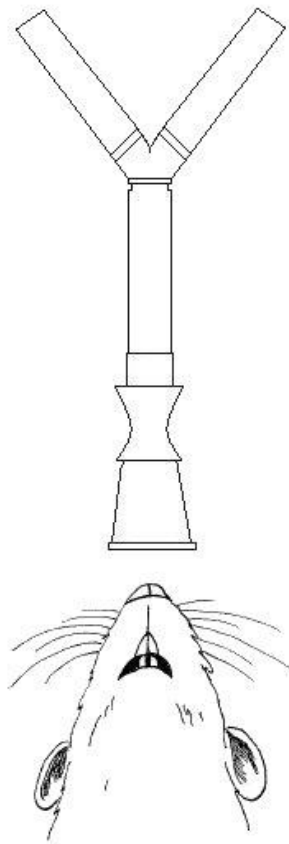
***It is important the implants remain in the sterile packages!***

3. Momentarily bring a strong magnet within approximately one inch of the implant in the package.
4. Once the implant is implanted leave the device ON. If a protocol requires the implant to be turned off, a new two point calibration should be performed after turning the implant back ON.

## Appendix B: Ventilation of the Animal

A ventilator is a necessary piece of equipment to maintain respiration for intra-thoracic surgery, such as cannulation of the heart. If the lungs are not manually inflated during surgery, the animal will experience difficulty breathing and could die. There are multiple types of rodent-sized ventilators commercially available. Choose the one that is appropriate for the intended species to be used.

There are two methods to ventilate the animal during surgery. One method is through intubation of the animal with endotracheal tubes. Different sizes of endotracheal tubes are available and the appropriate size should be used with the intended species to be used. **Contact the vendor of the endotracheal tubes for more information regarding appropriate sizes.** Another method of ventilation is by forcing air into the lungs via a snug-fitting nose cone<sup>2</sup>. This is achieved by placing the nose cone around the snout and then connecting the catheter to the ventilator. It must be secured snugly around the snout of the animal otherwise it will leak air and not properly inflate the lungs. The nose cone can then be connected to the tubing from the ventilator via luer lock fittings and additional tubing if necessary (See Figure 69). **Be sure that your ventilator is compatible with a nose cone before attempting this method.** For more information on where to purchase the nose cone, please refer to the Small Animal Surgical Supplies technical note on the DSI website.



**Figure 69: Nose cone for ventilation**

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<sup>2</sup> Rindfield T (Journal of Investigative Surgery) 25, 197-199, 2012

## Appendix C: Implantation of HD-S11-F2 with HD-XG

With the addition of a second frequency (F2) to the HD-S11 product line, researchers are now able to utilize unique solutions to study multiple parameters within one animal. Both the HD-S11-F2 and HD-XG devices may be implanted in a single animal to concurrently obtain cardiovascular and biopotential data with continuous glucose measurements.

Both the catheter and sensor tips must be located in free-flowing blood. The HD-XG sensor is manufactured at a fixed length and thus must be inserted directly into the abdominal aorta with the device body located intraperitoneally. The HD-S11-F2 may be inserted in the femoral artery with the device body placed subcutaneously on the flank, and the catheter tip must be advanced to the abdominal aorta, just cranial to the iliac bifurcation.

The abdominal aorta will be occluded just caudal to the renal vein and approximately 4-5 mm cranial to the iliac bifurcation. The sensor insertion site must be several millimeters cranial to the iliac bifurcation to prevent overlap of the catheter and sensor. After sensor insertion, it is recommended to release any tension, but leave the caudal-most occlusion suture in place. The femoral artery may then be catheterized and the caudal-most suture around the abdominal aorta may be used to gently elevate the aorta to gauge the insertion depth of the femoral catheter. The catheter should be advanced until the tip is cranial to the iliac bifurcation and caudal to the sensor insertion site. Once the femoral catheter is secured in the optimal location, the caudal-most occlusion suture may be removed.

It is recommended that the user consult the surgical manual for further detail on each surgical procedure.



**Figure 70: HD-XG device in intra-peritoneally, HD-S11 device subcutaneously on animal's left flank**

## Appendix D: Configuration Options

Many configurations are available to enable flexibility between studies.

All listed surgical approaches are endorsed by DSI's surgical support staff and therefore training is available for these methods on-site or at DSI headquarters. The surgical placement may vary depending on the animal model and experimentation with a non-functional training device is recommended before attempting a survival surgery. Surgical manuals are available for all procedures and videos are available for select procedures.

Papers or posters verifying these surgical methods are available via DSI's bibliography system found on the website. In unique applications, DSI may also be able to connect researchers together for further surgical or scientific development.

### HD-S10

DSI does not recommend the use of the HD-S10 for dP/dt analysis. Furthermore, DSI does not recommend use of the HD-S10 for right ventricular pressure or left ventricular pressure measurement.

270-0180XXX	PhysioCath Catheter		Suture Rib?	DSI Endorsed Surgical Approach		
	Length / Tip	Ligation Aide?		Animal Model	Device Placement	Catheter Placement Options
-001	8cm / 6mm tip		•	Rat	Intraperitoneal	<ul style="list-style-type: none"> <li>Systemic BP from the Descending Aorta</li> <li>Intra-Pleural Pressure</li> </ul>
					Subcutaneous	Systemic BP from the Femoral Artery
-002	10cm / 6mm tip		•	Rat	Intraperitoneal	Systemic BP from the Femoral Artery Pulmonary Artery Pressure
				Guinea Pig	Intraperitoneal	Systemic BP from the Descending Aorta
-003	15cm / 6mm tip		•	Ferret	Subcutaneous	Systemic BP from the Femoral Artery
-007	8cm / 3mm tip	•	•	Rat	Intraperitoneal	Bladder Pressure
-008	8cm /		•	Rat	Intraperitoneal	Intra-cavernosal Pressure

	4.5mm tip					
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### **HD-S11**

Only the 8cm catheter with a 6mm tip and ligation aide is recommended for dP/dt analysis in rodents.

270-0193XXX	PhysioCath Catheter		Lead Length	Suture Rib?	DSI Endorsed Surgical Approach		
	Length / Tip	Ligation Aide?			Animal Model	Device Placement	Catheter Placement Options
-001	8cm / 6mm tip		30cm	•	Rat	Intraperitoneal	<ul style="list-style-type: none"> <li>• Systemic BP from the Descending Aorta</li> <li>• Intra-Pleural Pressure</li> </ul>
-002	10cm / 6mm tip		30cm	•	Rat	Intraperitoneal	Systemic BP from the Femoral Artery
						Intraperitoneal	Pulmonary Artery Pressure
					Guinea Pig	Intraperitoneal	Systemic BP from Descending Aorta
-003	8cm / 6mm tip		30cm		Rat	Subcutaneous	Systemic BP from the Femoral Artery
-004	8cm / 6mm tip	•	30cm	•	Rat	Intraperitoneal	<ul style="list-style-type: none"> <li>• Left Ventricular Pressure</li> <li>• Right Ventricular Pressure</li> </ul>
-005	10cm / 6mm tip	•	30cm	•	Rabbit	Intraperitoneal	Right Ventricular Pressure*
-006	8cm / 4.5mm tip		30cm	•	Rat	Intraperitoneal	Intra-cavernosal Pressure
-007	8cm / 3mm tip	•	30cm	•	Rat	Intraperitoneal	Bladder Pressure

-008	10cm / 6mm tip		60cm	•	Ferret Rabbit	Intraperitoneal	Numerous Applications
-009	15cm / 6mm tip		60cm	•	Ferret	Intraperitoneal	<ul style="list-style-type: none"> <li>Systemic BP from Descending Aorta</li> <li>Systemic BP from Femoral Artery</li> </ul>
-010	8cm / 6mm tip	•	30cm		Rat	Subcutaneous	Numerous Applications

### **HD-S21**

- For any pulse wave velocity analysis the catheter lengths must be equal.
- Only the 8cm catheter with a 6mm tip and ligation aide is recommended for dP/dt analysis in rodents.

270-0192XXX	PhysioCath Catheter 1		PhysioCath Catheter 2			Suture Rib?	DSI Endorsed Surgical Approach		
	Length / Tip	Ligation	Length / Tip	Ligation	Biopotential Lead Length		Animal Model	Catheter Placement Options	
-001	8cm / 6mm		8cm / 6mm		30 cm	•	Rat	1 2	Two stomach pressures
-002	8cm / 4.5mm		8cm / 6mm		30 cm	•	Rat	1	Intra-cavernosal pressure
								2	Blood pressure via descending aorta
-003	8cm / 3mm	•	8cm / 6mm		30 cm	•	Rat	1	Bladder Pressure
								2	Blood pressure via descending aorta

-004	8cm / 6mm		10cm / 6mm		30 cm	•	Rat	1	PAP or RVP
								2	Blood pressure via descending aorta
-005	8cm / 6mm	•	10cm / 6mm		30 cm	•	Rat	1	LVP or RVP
								2	Blood pressure via descending aorta
-006	10cm / 6mm	•	10cm / 6mm		30 cm	•	Rat	1	RVP
								2	Blood pressure via descending aorta
-007	10cm / 6mm		10cm / 6mm		30 cm	•	Rat	1	PAP or Intra-Pleural Pressure (IPP)
								2	Blood pressure via descending aorta
-008	8cm / 6mm		15cm / 6mm		60 cm	•	Rabbit	1	LVP (if no suture aid is desired)
								2	Blood Pressure via femoral artery
-009	10cm / 6mm	•	15cm / 6mm		60 cm	•	Ferret G. Pig	1	LVP or RVP
								2	Blood pressure via descending aorta
-010	10cm / 6mm		15cm / 6mm		60 cm	•	G. Pig	1	PAP or RVP
								2	Blood pressure via descending aorta
							Rat	1	PAP

								2	Blood pressure via femoral
-011	8cm / 6mm	•	15cm / 6mm		60 cm	•	Rat	1	LVP
								2	Blood pressure via femoral
-012	8cm / 3mm	•	8cm / 4.5 mm		30 cm	•	Rat	1	Bladder pressures
								2	Intra-cavernosal pressures
-013	8cm / 6mm	•	8cm / 6mm	•	30 cm	•	Rat	1 2	LVP & RVP
-014	15cm / 6mm		15cm / 6mm		60 cm	•	Rat	1 2	Pulse Wave Velocity (equal catheter lengths required)
-015	8cm / 3mm	•	8cm / 3mm	•	30 cm	•	Rat	1 2	Intra-ocular & intra-cranial pressures
-017	10cm / 6mm		8cm / 3mm	•	30 cm	•	Rat	1	Blood Pressure via femoral artery
								2	Bladder Pressure